Sustainable and Secure Fish Farms: Understanding the Social Practices and Processes Relating to Aquaculture and Biosecurity

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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

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Abstract

This thesis examines what it means to do biosecurity and fish farming well on freshwater finfish (trout) farms in England and Wales. At the core of this question is what biosecurity means as attention shifts from disease pathways to animal health matters.

A mixed-method approach of survey data, embedded participant research alongside a Q-methodology was utilised to uncover a new understanding of what it really means to practice biosecurity on fish farms. By framing the research question with the conceptual lens of social practice theory, this research argues for a new understanding of why practices related to biosecurity occur and persist.

Consequently, this thesis offers five new contributions to biosecurity and aquaculture knowledge. Firstly, this thesis identifies the unique relationship between agents of the state tasked with monitoring and enforcing biosecurity policies and those fish farmers who must comply with such policies. Secondly, the omnipresent threat of endemic disease is highlighted as the most significant influencing factor for fish farmers across the industry. How they approach endemic disease issues reflects how they conceptualise the broader issues of biosecurity within the industry. Thirdly, the examination and argument for the important role that care occupies within the industry as a pillar of successful disease management. Fourthly, the suitability of social practice theory as a conceptual lens to examine this industry and the theoretical question of biosecurity provide a nuanced understanding of the subjectivities in doing biosecurity well. Fifthly, the importance of practices of care and how they relate to biosecurity practices on farms.

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Lastly, to my loving family. My supportive parents, ever encouraging and always understanding. Emily, your love, patience and hope are infinite.

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List of Acronyms

BTA	British Trout Association
BSE	Bovine Spongiform Encephalopathy
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
DEFRA	Department for Enviornment Food and Rural Affairs
ERM	Enteric Redmouth Disease
FHI	Fish Health Inspectorate
FMD	Foot and Mouth
FSA	Food Standards Association
IHN	Infectious Haematopoietic Necrosis
OIE	World Organisation for Animal Health
PSD	Puffy Skin Disease
RBS	Risk-Based Surveillance
RTFS	Rainbow Trout Fry Syndrome
VHS	Viral Haemorrhagic Septicaemia
WTO	World Trade Organisation

1. Biosecurity & Aquaculture: An Introduction

On a warm summer afternoon in the English countryside, a fish farmer is quietly gazing into a flat calm earth pond; the steady and patient flick of his wrist propels a small scoop of feed pellets skyward. The pellets disperse in the air, fanning out in their flight before landing like hailstones over the centre of the dark mass of life moving beneath the surface of the pond. The dark mass instantly reacts to the pellets as individual mouths begin to open and close with feverish intent. The peaceful calm is no longer present, replaced by splashing and thrashing as the pond's inhabitants emerge stimulated by the falling feed and a seemingly insatiable appetite. The unmistakable flashes of colour from the flanks of the rainbow trout catch the sun as bodies thrash and turn, breaking the water surface. The fish farmer is observing the movement pattern of the dark mass beneath the surface. Their collective interest in the falling pellets appears to wane all too abruptly after half a dozen scoop fulls of feed, the bodies returning to the slow circulation under then calming water surface.

Staring through the medium of water, the fish farmer tries to focus his gaze on the individuals within this slow circulating cluster of almost identical bodies. The fish farmer's skilled eyes are drawn to the outliers, not conforming to this rhythmic procession of movement beneath the surface. There, loitering by the water intake pipe is a small cluster of fish. On closer inspection, some individual fish are struggling to hold their direction while standing out from their pond-mates' uniformity through the abrasion marks along their flanks. A sense of worry fills the fish farmers as his eyes scan the pond for more irregularities to discover the lifeless bodies of eight rainbow trout exhibiting the same superficial marks, suspended near the surface of the water or pinned to the outflow grate. He collects a cumbersome net and a disposal bucket and begins to remove each dead fish with a skilled and practice movement. The fish, now out of the water, present clues to their fate. The raised swelling on their brightly coloured flanks, combined with the lethargic feeding display of the population and the warm summer weather, accounts for an unsettling scenario for the fish farmer. Could it be the emergent puffy skin disease that the Fish Health Inspectorate has warned *about, or is this another case of the endemic red mark disease? At that moment, the fish farmer is placed in an unpleasant situation, the choice between notifying the Fish Health Inspectorate, which may lead to movement restrictions, culling and loss of livelihood, or not reporting the suspicion in the hope that it is indeed an endemic condition. The later choice risks spreading the disease to other watercourses and catchment areas upon transportation of the live fish to buyers across the region.*

This research aims to determine a new understanding of the underlying drivers of the management and mitigation practices related to biosecurity and fish health in the freshwater finfish industry of England and Wales.

The opening vignette draws upon experiences on farms and conversations with fish farmers about the precarious nature of life in the ponds and raceways of English and Welsh fish farms and the challenging task of securing biosecurity. This research is warranted to critically engage with the perspectives of those individuals working within the English and Welsh finfish sector for the first time on how biosecurity is understood and implemented in practice. To this point, critical stakeholders within the industry (fish farmers, fish health inspectors, feed company reps and fish vets) have not been engaged with to understand current approaches to disease management better and better inform future policy development and implementation.

This research identifies this gap in available knowledge and argues for key stakeholders' place as a valuable resource in the formulation and implementation of policy relating to biosecurity and disease management within the industry. Enticott and Wilkinson argue that "being open to different forms of knowledge and expertise has much to offer attempts to understand and improve biosecurity practices" (2013:91). This thesis offers this new perspective on how biosecurity is conceptualised and practised at farm level.

1.1 Aims & Objectives

At the core of this research project are the following aims.

1) This research aims to determine a new understanding of the underlying drivers of the management and mitigation practices related to biosecurity and fish health in the freshwater finfish industry of England and Wales.
2) To contribute to the current academic knowledge of biosecurity through a theoretical framework of practice theory, a previously unutilised framework with respect to aquaculture.

These aims will be achieved by completing the following objectives:

1) To investigate the range of the finfish farming industry in England and Wales and highlight the key drivers of fish health, security and disease.
2) To identify and explore the factors (social, environmental, market, regulatory, etc.) that influence behaviour and attitudes towards biosecurity, faced by fish farmers on a day-to-day basis. Practice theory will be vital to unpack the complexity of these interactions and links between the varying elements comprising the aquaculture industry.
3) To investigate the potential for divergent opinions between fish farmers and regulators on what constitutes biosecurity, the hierarchy of biosecurity concerns and how to best implement management practices on farm level.

1.2 Setting the Scene & Theoretical frameworks

This chapter will now introduce the topic of biosecurity and the finfish sector of England and Wales before providing an overview of the forthcoming theoretical, methodological and empirical chapters to help guide the reader through the development of the research.

1.2.1 Biosecurity

Braun describes biosecurity as 'those knowledges, techniques, practices and institutions whose concern is to secure valued forms of life from biological risk' (2013:45). However, biosecurity management's implementation displays a heterogeneity of practice as individual biological and disease risks often require complex and variable responses due to geographical, social, environmental and pathogen factors. Braun documents the unruly assemblages in the efforts to contain food handling protocols and personal hygiene practices, surround us in everyday life and exhibit power over life (Foucault, 1991). This approach is evident as society attempts to govern and control the circulation of such unwanted forms of life. Traditionally, biosecurity can be examined in two approaches,

1) Preventative: as preventative measures against a threat to reduce the likelihood of emergence or incursion of biological life that has been informed and identified by a formal risk assessment; the preventive approach is actualised through vaccination protocols and movement restrictions on biological life.

2) Reactive: measures of response including quarantine and culling that may be enacted upon the failure of the preventative approach to stopping a disease outbreak or the incursion of a geographical area by an invasive life form. Within the context of this research, the life worth securing is that of farmed trout which are produced in England and Wales. The unruly life forms which seek to threaten the industry include a variety of bacterial, viral and parasitic disease threats which range from reoccurring endemic diseases such as Enteric Redmouth (ERM) to non-native diseases Viral Haemorrhagic Septicaemia (VHS) and Infectious Haematopoietic Necrosis (IHN).

Biosecurity and the secure circulation of life are integral parts of the food production system and trade. Trout farming in England and Wales occupies an unusual position within the broader scope of food production. The industry is relatively niche, with under 150 operational farms in 2019 and no new sites opened in the last decade. The trout sector is divided between; 1) the small to medium-sized restocking fish farms. Fish farms of this nature cater to the angling industry by producing and supplying fisheries[1] with healthy and vibrant live fish that are aesthetically impressive to the eye. These fish are used to restock managed lakes and waterways open to the public or members to fish recreationally. 2) Table producers are typically more extensive operations or multi-site operations which produce trout to a prescribed size and weight at the behest of large retail multiples, which require a reliable and uniform product that will be stocked in stores across the UK.

The trout industry's disease situation has demonstrated an outward degree of stability regarding outbreaks of notifiable disease in recent history. The last reported instance of a non-native and notifiable disease outbreak Viral hemorrhagic septicemia (VHS) occurred in North Yorkshire in May 2006 (Stone et al., 2008). Although VHS is a considerable threat to the industry, other emergent threats have garnered fish farmers and scientists' attention. One such emergent threat is Puffy Skin disease (PSD), a severe skin condition affecting rainbow trout farms in the UK. The disease has been described (Hughes in Maddocks, 2014) as the fourth most economically significant disease affecting large fish production in England and Wales. Additionally, the industry must contend with a range of endemic and reoccurring diseases such as Enteric Redmouth (ERM) and Proliferative kidney disease (PKD).

This research will expand the current academic knowledge of the fish farming industry's attitudes towards biosecurity and fish health management through a rapid-evidence review of the biosecurity literature directly related to freshwater

[1] Fisheries within the context of this work refers to bodies of water which are managed by individuals or organsations for the purpose of recreational angling. These locations operate on an exclusive membership model or pay-as-you go day rates. The fisheries of England and Wales are the primary market for the restocking trout sector.

salmonid aquaculture. A necessity as currently, the industry structure of highly productive table producers and smaller restocker struggle to connect with the policy development process. Farmers risk being left behind, out of touch with why biosecurity policies and practices matter to them and, in turn, to their entire industry. With a more developed connection between fish farmers and policymakers on the industry's issues, the opportunity for two-way knowledge transfer to occur in a manner that further safeguards the longevity of the industry and builds resilience to the threat of outbreak through doing fish farming well.

At the core of this research is biosecurity within the trout industry of England and Wales. This research will address the industry's key disease threats and investigate the embedded attitudes and practices relating to disease management and biosecurity on-site to better inform policy and surveillance strategies relating to biosecurity in aquaculture.

Through practice theory (Shove et al, 2012), this research identifies encounters and moments shared between fish and fish farmers where husbandry and biosecurity practices come to the fore. This research uncovers the underlying and lesser-explored concept of practices of care within aquaculture through a detailed embedded ethnographic approach (Mol, 2008). This shift in theoretical focus from practice theory identified the subtle moments and interactions of care to one that places care practices as an essential component of biosecurity practices.

The following chapter summaries will provide the reader with a guided rationale to the structure of the thesis. In addition, the chapter summaries navigate the reader through the selected theoretical approaches of social practice theory (Shove et al., 2012) and later care (Mol, 2008) and set out the research methods chosen to examine this question of biosecurity and disease management in aquaculture.

1.2.2 Practice theory & Care Practices

Understanding the different perspectives and reasoning that a group of people have on a given topic or issue can be a complex and often challenging task. Often such attempts to understand a topic are overtly superficial, presenting a general theme without developing an understanding of the root causes or motivations behind a given behaviour or practice. Attitudes and practices relating to biosecurity require a robust examination of actors' underlying motivations in securing biological life. Practice theory is presented as a valuable lens through which this research project conceptualised and implemented the ethnographic research (Chapter 5) by allowing the researcher to identify moments within the encounters between the human-animal relationships of fish farmers and their stock.

Practice theory allows for a non-deterministic approach to human behaviour, which has been applied to a diverse selection of topics, including neuroscience (Lizardo, 2007); urban transport practices (Barr, 2015), domestic consumption practices and climate change policy (Shove, 2010) and others. Practice, within social practice theory, is defined by Reckwitz as 'a routinised type of behaviour which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, 'things' and tier use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge' (2002:249). Similarly, Schatzki argues that a practice is a 'bundle' of activities, linked together (2002:71). By understanding this nexus, practice theory can be effectively applied to complex networks of human practice such as the 'integrative practices' (Schatzki, 1996:98) of biosecurity management in aquaculture. The approach is suitable to aquaculture as it shifts the focus from away from the individual and onto the practice itself. Practice theory facilitates a mode of observing the farm tasks of vaccinating, removing mortalities and daily feeding routines.

Practice theory remains non-voluntarist. It investigates the interrelations between actors to identify opportunities and barriers to change. This is a key consideration for this project as the interactions between fish farmers, the state, and other stakeholders are of considerable interest. It also recognises the possibility of unintended consequences of action in a world where practices interact, diffuse and borrow from other practices (Warde, 2005). Schatzki suggests that practices can overlap and become interwoven, forming a 'densely interwoven mats' (2002:87), an awareness of this complexity provides a conceptual lens to understand a niche food production industry and its approach to biosecurity and disease management.

Social practice theory offers the potential to approach this question of how to understand biosecurity in aquaculture differently. This is particularly relevant to the focus elements involved in practices. How practices emerge as the elements of competence, social meaning and material (Shove et al., 2012) come together is of particular interest in understanding what drives biosecurity practices. How these bonds are formed, sustained and broken provides practice theory with the conceptual platform to engage in why specific actions form accepted practices over others. Applied to the aquaculture industry, this allows for an understanding of the industry's existing practices from mortality record and vaccination protocols. Practice theory can highlight the interactions, relationships and power dynamics (Foucault, 1979) between actors (fish farmers, inspectors) within the aquaculture industry. While providing new knowledge on the practice of securing a fish farm and, in turn, the wider trout industry from the threat of disease outbreak.

As the research developed, it was apparent that care practices were of significant importance to what it means to do biosecurity and fish farming on sites across England and Wales. To reflect this emergence of care practices as a key finding of this research, a conceptual shift occurs (Chapter 5 & 6) as the work of Mol (2018) is introduced to develop the valuable revelations on relational care. This shift of conceptual focus reflects the development of this project and the broader biosecurity debate, with Maye and Chan (2020) calling for a greater emphasis on care in biosecurity.

1.3 Research methods

To engage with and develop knowledge on an industry that until now has undergone limited academic focus it was necessary to develop knowledge on the current status of the trout industry, identify the traits and challenges that present before critically developing an understanding of the competence, motivation and material underpinning the practices relating to biosecurity and fish health management.

The four-part methodological approach was designed to uncover distinct information relating to attitudes to biosecurity, the presence of care and risk-based surveillance on trout farms.

Firstly, a postal and online survey was designed to examine trout farmers' experiences across England and Wales was placed in the field in January 2017. This method was utilised to provide an overview of; 1) disease issues facing fish farmers; 2) attitudes to regulation; 3) current perspectives on biosecurity. Supporting this data is a rapid evidence review of the current research trends on biosecurity and trout aquaculture located in the literature review (2.3).

Secondly, this research utilised a Q Methodology to identify the subtle differences in perspectives on biosecurity and disease management that exist within the stakeholders of the trout industry—pioneered by Stephenson (1935) who first adapted the quantitative method of factor analysis through the inversion of the factor analytic method (Watts and Stenner, 2005). Q methodology utilises factor analysis and qualitative interpretation to identify and define shared participant commonality on an issue effectively. Since its introduction, Q methodology has featured in a broad range of the social sciences including; psychology (Stainton Rogers, 1995; Stenner and Stainton Rogers, 1998; Stenner and Watts, 1998), geography (Previte et al., 2007; Price et al., 2017), environmental science (Webler et al., 2009) and political science (Brown, 1980). Good (2000) argues that for one to fully comprehend Q methodology one must identify the method as a gestalt procedure. This emphasis on the collective ensures that the subject matter may not be divided into themes in the manner of forms of discursive or interpretative phenomenology. Instead, Q methodology is adept at uncovering the interconnectivity of these themes by participant groups. In essence, this holistic approach is more akin to narrative analysis (Crossley, 2000).

Thirdly, to develop an understanding of the on-the-ground practices of fish farming across the trout industry, required a qualitative approach. To truly understand the practices of fish farming, it was of paramount concern to develop and undertake a series of embedded ethnographic visits on a variety of trout aquaculture sites including hatcheries, table producers and restocking farms in England during 2017. The three-stage process, as described by Crang and Cook

(2007), offers the opportunity to gain access to a group or community, in this case, the trout production industry, in which they can live or work among those individuals and stakeholders, to gather their thoughts and perspective which are the focus of the research in question before returning to an academic environment and distilling the fieldwork accounts. This incredibly hands-on method allowed the researcher to develop an embedded knowledge and skill set for a wide variety of the daily practices essential to the maintenance and management of a fish farm (Spencer, 1989; Tedlock, 1991). Crucial to this method's development was the use of practice theory (Shove et al., 2008) to identify and critically engage with several husbandry practices essential to managing life on a fish farm. Feeding, cleaning, grading, fertilisation of eggs, mortality removal and vaccination are among a few of the tasks and skills which were undertaken and developed through participant observation alongside experienced fish farmers provided an ethnographic understanding of the stressors present for both the fish and the fish farmer as they try to balance a healthy population with a profit-making business plan. This research phase was essential in understanding the reasoning behind the attitudes and approaches to biosecurity and the reasoning underpinning such approaches.

Fourthly, there was a need to understand the industry from the agency of the state tasked with securing aquatic life on fish farms in England and Wales. Inspired by Bingham and Lavau (2012) work in the food safety sector, who shadowed the agents of the state in their routine inspection practice provided a unique insight into the strategies and power dynamics at play within the food safety arena. This research joined field inspectors as they carried out a series of annual monitoring visits to fish farmers in the south of England. This approach facilitated the development of knowledge surrounding risk-based surveillance practices and their manifestation in the field.

1.4 Biosecurity in aquaculture

The approaches that provide a contemporary critical analysis of biosecurity include several diverse areas of interest ranging from governmentality and biopolitics (Braun, 2006), uncertainty and indeterminacy and risk (Donaldson, 2008; Hinchliffe, 2001) and co-produced networks of materiality, circulation and mobility (Braun, 2008; Barker, 2010). Chapter 4, the first empirical chapter of this thesis, will investigate the current biosecurity approaches to trout aquaculture and offer a unique perspective towards biosecurity issues within the aquaculture industry in England and Wales. The focus of this research is that of the 'agricultural assemblage' of aquaculture. In an interconnected world where global trade and the circulation of life, both large and microscopic are prevalent, biosecurity has emerged as a dominant paradigm to make life safe. The prominent biosecurity model active within the UK is the closure model of biosecurity, a model that utilises the concepts' sanitation, surveillance and integration' (Hinchliffe et al., 2013) to promote and safeguard trade within the industry. This research will question the applicability of closure measures within aquaculture and explore its focus on disease within the industry.

Currently, attention has focussed for the most part on emergent disease such as Puffy Skin disease (Peeler et al., 2014; Maddocks et al., 2015) and non-native disease threats VHS, IHN (Stone et al., 2008). This focus has justifiably addressed the industry's most significant economic threats through these emergent and trade limiting conditions. However, fish farms in England and Wales are subjected to other endemic disease issues annually. These endemic concerns and how they alter the daily biosecurity practices on fish farms are so far unaccounted for.

This research utilised a postal survey to generate an overview of biosecurity within the trout industry. It provided new insights into disease frequency and disease concerns among fish farmers. From this data, some important trends began to emerge, including the prominence of endemic disease in fish farmers' minds and the apparent strong institutional relationship of trust between fish farmers and the regulatory agency responsible for biosecurity within the industry, the Fish Health Inspectorate (FHI).

To further capture the industry’s perspective on biosecurity, a Q-sort was developed to extract a more nuanced understanding of biosecurity sentiment across fish farmers, inspectors and stakeholders. The utilisation of a Q-methodology provides a unique lens to view the issue of biosecurity and disease management (Watts and Stenner, 2012). The approach incorporates a gestalt view to identifying the subtleties concerning surveillance, biosecurity and fish health amongst participants from regulatory roles to fish farmers. The Q-methodology revealed a significant consensus among participants on the importance of biosecurity to go beyond strictly regulatory compliance and incorporate caring relationships between fish farmers and their stock and inspectors and their regulatory roles in the industry.

1.5 Care Practices in Aquaculture

The prevailing surveillance strategy within aquaculture is risk-based surveillance. This method has proven effective in securing the English and Welsh trout industry from non-native disease threats such as IHN and VHS and remains the foundation on which European biosecurity protocols are developed under the EU Directive 2006/88 (Anon., 2006). What remains somewhat unaccounted for is the circulation of undocumented endemic disease within the industry. Total eradication of such endemic diseases is a utopian ideal, unlike terrestrial agriculture where systematic testing, eradication or vaccination may be introduced; endemic aquaculture diseases circulate through the watercourses and catchment areas across the country. Their existence is intertwined with wild and captive host populations and the medium of water and poses a complex problem for fish farmers. However, the daily practices of fish farmers can increase the resilience of fish populations, boosting overall population health and disease resilience.

Chapter 5 will expand on the interspecies relationship between fish farmer and fish and seek to introduce the concept of care practices and domestication that exist in what is a complex inter-species partnership. At this point, the thesis pivots to a focus on the identification of care and practices of care within aquaculture as a critically important contributor to industry-wide biosecurity. The emergence of care (Mol, 2008) will prove to be an important contribution to new understandings of farm-level and industry-wide biosecurity implementation and governance.

The freshwater finfish aquaculture industry is distinctly split between table producers and restocking fish farmers. By implementing ethnography across the production styles, this research seeks to uncover and illustrate the practices and processes relating to biosecurity enacted daily on fish farms. The development of the table sector into its current model of intensive production may have the potential to deflect the fish farmers' attention away from the actual production process and the individual fish-fish farmer relationship through the scale of production, audit requirements, and economic factors. Instead, this development has enhanced the view of fish as a 'crop' to be harvested rather than individual animals to be cared for (Lund et al., 2007:114). How do we care for fish in aquaculture, and why is it a complicated endeavour? Lien (2015) offers us the concept of the fish as an unfamiliar entity, 'fish are cold. They live in water. They are mostly out of sight. They are silent. Their staring eyes show no visible emotion. Their body language is difficult to interpret' (2015:3) is evocative and mysterious and furthers the separation in this human-animal relationship. Lund et al., (2007) advance this argument by drawing attention to the communication difficulties arising from the phenomenological experience between species as profoundly different in the case of humans and the fish, which is likely to have effects on attitudes and actions of the fish farmer. The cold-blooded nature of the fish and their requirement to inhabit an environment distinct from our own sets them apart from terrestrially farmed animals. Distinct from terrestrial animals, fish have no endearing facial features or expressions which we understand spontaneously, fish are without sound, silent in their environment, there are no audio cues detectable or recognisable for stress and unhappiness that may encourage an empathetic response in a manner that Tinbergen (1988) described as the 'Bambi Effect'.

Chapter 5 explores the relational dynamics of care that emerge between human and fish. The vast multitudes of fish kept on a UK fish farm makes it difficult for an observer to consider an individual fish, or even to view them in terms of individual animals, particularly in the table sector where uniformity of size and weight is targeted. Therefore, unlike the human relation to farmed terrestrial species, animal welfare concerns towards fish are scarcely enhanced by human empathy caused by identifiable similarities between species and facilitated by recognising emotions in individual animals (Lund et al., 2007). Domestication is a 'two-way process' (Lien, 2015:3), and these relationships are essential in aquaculture, as with any animal production endeavour. This research will investigate how fish farmers engage with these challenges of interspecies life and discuss how these daily practices form an integral part of supporting a fish population that is resilient to external health and disease threats. Chapter 5 introduces the importance of relational dynamics on fish farms and the human-animal relationship of care. This concept will be further developed in chapter 6 to explore the relational dynamics between fish farmers and those tasked with regulating the aquaculture industry (FHI).

1.6 Surveillance, Monitoring and Inspection

Chapter 6 builds on the relational care exhibited between fish farmers and fish. It explores practices of care from the perspective of caring for the industry. This is accomplished by the examination of regulatory and stakeholder relations and the shadowing of annual monitoring site visits. Risk-based surveillance and the defence of borders to 'keep out' potentially problematic pathogens and pests is a dominant narrative in biosecurity policy and practice (Potter, 2013). The prevailing surveillance strategies emerge from international agreements and guidelines from the World Trade Organisation (WTO), the World Organisation for Animal Health (OIE) and others. In the trout industry, the European Council Directive 2006/88/EC (Anon., 2006) on aquatic animal health as its mission seeks to facilitate trade and improve fish health. The Directive stipulates the requirement for trade to occur between areas of equal health status or areas of higher health status to areas of lower health status, with the importing country in question retaining the responsibility of analysing the risk attached to the commodities they import (FAO, 2004). The five disease categories named in the Directive in rank from highest to lowest level include: 1) declared disease-free; 2) not declared disease-free, but subject to a surveillance programme; 3) unknown; 4) subject to an eradication programme and finally 5) known to be infected (Anon., 2006). The aforementioned disease statuses can be applied to a country, a region or even a small cluster of farms or indeed an individual farm, allowing for the compartmentalisation of an industry where movement pathways can be verified. The Directive requires Risk-based surveillance to maintain the disease status of the area in question, with reference being drawn to the likelihood a farm may encounter or spread disease requires the individual surveillance of each fish farm in operation. The surveillance strategy in operation within the freshwater aquaculture industry of England and Wales is risk-based surveillance.

Oidtmann et al., (2011) have taken the lead on this matter by developing a risk-based approach to systematically address the surveillance requirements for introducing trade limiting notifiable disease in the trout industry. Through a series of workshops with key stakeholders in the industry, the entry points and disease routes were identified and weighted to develop a transparent approach to the ranking of farms for disease transmission. What emerged from this ranking was a risk-based model for pathogen spread. This method has proven effective in securing the industry from outside threats. Yet threats remain. Peeler et al. (2011) highlight the role of fertilised eggs (embryos) as they are moved in large volumes and internationally for salmonid aquaculture. Although subjected to disinfection techniques, the transmission of disease cannot be equivocally ruled out. Instead, the transportation of eggs is seen as less risky than the transportation of live animals between farms. To explore this topic, a series of participant shadowing visits were carried out in conjunction with the annual monitoring schedule of the FHI. These opportunities provided a unique view of the manifestations of risk-based surveillance and relational biosecurity dynamics in the field. This method will examine the role of those tasked with implementing the protocol and the industry's precarious nature in the face of such trade limiting consequences.

Similarly to the proceeding chapter, care practices' role is integral to the relational approach to biosecurity that creates and maintains the interactions between fish farmers and inspectors. Together with Chapter 5, this chapter's findings further the growing trend of academic research that places care and care practices as key contributors to the implementation of broader industry level biosecurity objectives as supported by Higgins et al. (2018).

2. Biosecurity & Social Practice Theory

Four fish farmers stand around an outdoor table, heads bent, each farmer holding a small injection gun in one hand linked to a suspended vaccine bottle by clear plastic tubing. Their hands are hurriedly working through the mound of silver and black bodies which occupy the table. The fish are docile, unmoving. Their bodies are momentarily still, having been dipped into an anaesthetic bath before being placed on the table. At this point, their existence is firmly in the control of the fish farmers gathered around the table. The farmers work with feverish intent, their skilled hands moving with rapid efficiency as they pick up each wet and slimy individual from the pile. A quick turn of the wrist rotates the body of the fish, and a pull of the trigger finger injects in the abdomen with the ERM vaccine. This individual action, lasting mere seconds, is repeated as the seemingly never-ending pile of fish is added to by net full upon net full of freshly anaesthetised bodies that keep the table service covered. With thirty thousand fish scheduled to be vaccinated in one morning, there is little time to spare. There is no chatting amongst the men. There is a focused intensity in their work. The silence surrounding the men is only broken by the occasional instruction from the most experienced farmer to the one tasked with providing the table with a supply of anaesthetised fish to vaccinate.

As each fish is selected, the farmer's skilled eyes scan the body for signs of deformities that may affect the fish as it matures. Over five to seven seconds, the farmer decides on the life or death of the juvenile fish, a decision made based on their experience and knowledge. Does the fish show signs of deformities, is it drastically undersized and will it compete with its pond-mates or will its fragility of life offer a potential host body to an unwanted disease? Unconforming bodies are discarded. Those who conform to the preordained healthy image are returned to their pond-mates as vaccinated individuals.

As the rain begins to fall, the task becomes more challenging for the farmers. The rain adds to the fish bodies' slippy nature, and any protective gloves are soon discarded for a better grip on the flesh. The natural mucus that surrounds the fish *bodies and the rain proves a tricky proposition for the farmers. Accidental poking and self-injection is not uncommon and have been known to incapacitate those unfortunate enough for several days severely. The rain also accelerates the anaesthetic recovery time. With the fish exhibiting signs of life on the table only adds to the difficulty of the task as the farmers struggle to grasp their now twitching and alert targets in claw-like grips paying extra care not to accidentally inject the vaccine into their unprotected hands and fingers as they hurriedly make their way through the unvaccinated fish.*

2.1 Introduction

This research will draw upon social practice theory, aquaculture knowledge and the current academic understanding of biosecurity by investigating what it means to do fish farming well in conjunction with biosecurity and disease management in the trout industry of England and Wales. The application of social practice theory to this question of biosecurity will uncover new perspectives on what drives biosecurity in fish farming. A social practice approach shines a light on biosecurity and disease management in a manner that has not been applied to UK aquaculture.

This chapter will explore the current academic knowledge of biosecurity, with a particular focus on agricultural systems. Hinchliffe (2007) argues that disease is always more than a matter of infection: it is a pathogenic entanglement of hosts, environments and microbes. This chapter will address these links to develop a robust understanding of biosecurity. The theoretical background and evolution of this area of inquiry will be examined. It will provide an informed perspective on the current attitudes surrounding control and circulation of welcome and unwelcome life within agricultural or aquaculture assemblages.

After engaging with biosecurity, we are left with the question of applying a social science lens to understand the practical implementation of biosecurity. Indeed, the selection of the most suitable social science lens is fundamentally important. This chapter will explore this choice before developing the chosen theoretical framework of social practice theory. Social practice theory provides an alternative to behavioural modelling or individualism, it shifts the focus away from the individuals who perform them and onto the everyday or routine instances of social practices such as driving, shopping, playing sport etc. Social practice theory goes beyond individual decision-making and focuses on the 'doing' (Shove and Warde, 2002). Instead, it labels individuals as 'carriers' of practice that move through time maintaining the existence of the practice and facilitating its uptake by others (Reckwitz, 2002). This chapter will examine social practice theory, its theoretical origins and the suitability of this theoretical approach to this project. To date, practice theory has not been applied to issues relating to biosecurity and aquaculture. This gap in the existing academic knowledge ideally positions this research to further develop the concept of social practice theory and the understanding of biosecurity in trout aquaculture.

2.2 Understanding Biosecurity

Biosecurity exists for many as a predominately hidden process, located in the background of everyday life. For many, biosecurity remains hidden from view until moments of crisis. Such moments of crisis extend from the development of biological weapons, agricultural disease events and pandemics. Biosecurity exists within industry and policy as a never-ending process, hidden from the public view and enacted in a variety of strategic forms to control life. The United Nations Food and Agriculture Organization (FAO) defines biosecurity as follows: 'biosecurity broadly describes the process and objective of managing biological risks associated with food and agriculture in a holistic manner' (FAO, 2003:1). Donaldson (2013) remarks on the FAO's attempt to define its use within policy yet retain the varied conceptualisations of biosecurity. The FAO is the primary international organisation promoting biosecurity; however, it is not alone as the Office International des Epizooties (OIE) or World Organization for Animal Health is heavily invested in this area. Donaldson outlines the Importance of the Animal Health Act 1981 as amended. This legislation is the focal point by which competent authorities operate (2013:63). The responsible authority in England and Wales is the Centre for Environment, Fisheries and Aquaculture Science (Cefas) and the Fish Health Inspectorate (FHI). How these organisations influence and trace biosecurity practice on the ground is a challenge for policymakers globally.

Historical measures to control disease through closure (Donaldson, 2013) have evolved into what Hinchliffe et al., (2013:532) describes as 'a set of narratives, technologies and practices, which together are increasingly labelled as biosecurity'. Indeed current conceptualisation of biosecurity is the state and intrastate response to the cross-boundary movements of non-human living things, particularly those organisms that are considered a threat to human, ecological and economic conditions. However, conceptually biosecurity is an amalgamation of several approaches to how to best secure, valued forms of organic life. Braun (2013:45) describes biosecurity as 'those knowledges, techniques, practices and institutions whose concern is to secure valued forms of life from biological risks'. The following sections shall examine the prominent trends in biosecurity, challenges facing the concept and the practicality of the implementation of biosecurity policies.

2.2.1 Biosecurity beginnings

The theoretical perspectives which provide the foundation of biosecurity include several collective approaches ranging from governmentality and biopolitics (Braun, 2006), uncertainty and indeterminacy and risk (Donaldson, 2008; Hinchliffe, 2001) and co-produced networks of materiality, circulation and mobility (Braun, 2008; Barker, 2010). Baker's (2013:5) perspective on what' biosecurity actually entails is itself up for debate, shifting across spatial-temporal and discursive contexts. In general terms, biosecurity can be described as the attempted management or control of unruly biological matter, ranging from microbes and viruses to invasive plants and animals (2013:5). Baker's use of 'unruly' is worthy of note. Biosecurity denotes the division of life into the acceptable and the unacceptable categories, to apply the label of 'unruly' to biological life provides a justification to restrict and regulate life through the mechanisms of the state to exert control through biopolitics (Foucault, 1979). Biosecurity has emerged as a way to manage the movements of undesired pests and diseases within geographical areas or national borders and, more commonly between national borders. Attention is focused on nation-states and their disease statuses. These regional disease zones sometimes map on to other distinctions between the global North and South or rich and poor, mappings that are far from accidental and not without consequence to trade and movement of biological life (Davis, 2005).

Measures to restrict disease spread can be documented throughout history. Elbe (2016) writes about 'The Ban' as the oldest and most rudimentary acts of attempting to control and limit the spread of infectious diseases. Although rudimentary, this ban was designed to exclude individuals who were deemed ill from the rest of society. This was manifested as physical exclusion, which can be seen through leper colonies dating back to ancient Roman times and lasting until the 19th century. As Elbe (ibid) notes, such actions may appear archaic, yet they have persisted and exist within biosecurity practices to this day. Infected animals are segregated from healthy peers while stringent measures are adhered to, therefore reducing the chances of the infection entering into a farm. Other biosecurity parallels can be drawn from historic disease management practices such as the burial of plague and cholera victims in the UK. At the time, the established practice was to treat the deceased's bodies with lime and interning the dead in an area that has been segregated to contain the potential spread of disease to the broader population.

Through time, historical practices have evolved and have adapted to current biosecurity threats. Within countries, specific sites are earmarked as specifically crucial to biosecurity: these include airports, seaports and increasingly farms (Donaldson and Wood, 2004). These locations act as nodes on the global map to spread organic life, and efforts to restrict and examine the movement of all forms of life through these zones are common practice. However, when delving deeper into the meanings and usages of biosecurity, 'it is immediately clear that variation exists' (Barker, 2013:5). Barker's suggestion of a variation within biosecurity helps contextualise the multifaceted approaches to biosecurity, varying across the nation-states. Biosecurity operates across various regulatory scales as stipulated by a local or national government and other organisation. Biosecurity presents at least three frameworks that will now be introduced in detail.

The first approach to biosecurity focuses on attempts to control and manage the circulation of unwanted biological life in the form of pests and diseases within the agricultural landscape. This form of biosecurity is commonly associated with European agriculture policy. Policies of this nature have, in the past, become highly visible in periods of a disease outbreak. It is evident in the visually evocative containment and control measures draw a striking comparison to the countryside. Forms of containment and control are not unusual or groundbreaking in design but serve as regulatory enforcement tools with the practice of isolation, disinfection, restrictions and compulsory culling embedded in this type of biosecurity. Such actions involve both the categorisation of territorial units, from the infected, soon to be contained and the disease-free area requiring protection and the regulation of the movements of life (Hinchliffe and Bingham, 2008). This form of biosecurity became visible through the Foot and

Mouth Disease (FMD) outbreak that gripped the UK countryside in 2001. The outbreak was felt heaviest among the farming and rural communities who witnessed farm closures and culling operations. Biosecurity was not limited to such rural communities as movement restrictions were imposed on areas of the countryside, and the uncertainty surrounding the risk of spread forced the suspension of public events, including several high-profile Six Nations matches (The Guardian, 2001).

The second approach to biosecurity involves a policy direction that focuses on restricting invasive species from entering an area and the subsequent effect on the indigenous flora and fauna (Bright, 1999). This approach to biosecurity is prominent in Australia and New Zealand, where the existing geographical conditions provide a natural barrier restricting the movement of most organisms before human interference. These locations are separated by considerable ocean expanse from other landmasses. Until the age of exploration, these landmasses were effectively isolated from the ingress of non-native flora and fauna, therefore, facilitating the indigenous animal and plant life to develop in some cases without species in direct competition or the risk of contact with species capable of carrying a disease. The advent of maritime trade facilitated the spread of new life forms to these remote regions. The spread of these plant and animals was both accidental in the form of rats aboard ships and on purpose as the 1870's example of the introduction of the North American grey squirrel into Britain, as a fashionable addition to country estates.

Bright (1999) equates this form of biological spread to globalisation. The increase and integration of global trade, transportation and economic activities have been at the forefront for accelerated disease spread and 'bioinvasion' emerge. Subsequently, the measures to restrict non-native organisms is a prominent feature of the biosecurity landscape, and this is represented through the direction of biosecurity integrated policy. These measures have been popularised through media portrayal in televisions' Border Security: Australia's Front Line', further embedding this practice of control in the public consciousness. Bridging the gap between stakeholders and the public, by creating the paradigm that biosecurity is a shared responsibility. The recent example of Tasmanian farmer Letetia Anne

Ware illustrates the severity of reprimand in cases where national biosecurity policy is circumvented. In September 2019, Ware was found guilty of importing garlic bulbs from the United States of America and Canada demonstrates the severity of Australian biosecurity law. The offending garlic bulbs were potential carriers of the Xylella dastidiosa bacterium. The Xylella dastidiosa bacterium is designated as a threat to national plant biosecurity in Australia. Notably, Ware's contemporaries in the Australian Garlic Industry Association issued a strong statement condemning Ware's actions. 'The board strongly condemns any behaviour that jeopardises biosecurity or the Australian agricultural industry' (The Guardian, 2019).

The third approach to biosecurity focuses on the threat to populations through bioterrorism. This approach is particularly attentive to reducing the risks of microbiological materials being used as weapons. This type of biosecurity has emerged in a post 9/11 landscape and has gained traction in light of the current state of geopolitical conflicts and the increase in terror attacks (Hinchliffe et al., 2017). These elements and practices combine geopolitics and biogeography as real tensions emerge between movement and stasis, nations and natures and the circulation of life (Clark, 2002). Although a prominent area of policy development, particularly in North America, this research will not focus on this specific approach to biosecurity. Challenges exist in the formulation and implementation of biosecurity policies and practices. Biosecurity has focused on the 'four Ts' of trade, travel, transport and tourism to explain the dynamics of disease movements throughout the world (Waage and Mumford, 2008). The four elements provide a difficult balancing act for policymakers, who aim to reduce the risk of disease spread while maintaining the relative freedom of movement and circulation of goods and people within a globally connected world.

However, such approaches are subject to critique. Collier and Lakoff (2004) argue that biosecurity should be divided into four domains: emerging infectious disease; bioterrorism; the cutting-edge life sciences; and food safety. There is a growing consensus for an additional fifth domain, that of 'the macro-biotic realm of invasive plants and animals (Hinchliffe et al., (2017) that includes the work of Tomlinson and Potter (2010) that focuses on microbial diseases of trees and wider concerns for landscape and ecological security (Barker, 2010). These contrasting perspectives offer unique opportunities to explore a variety of issues through biosecurity. The following sections will focus on the challenges of biosecurity and the dynamic policy environment in which biosecurity is formed. How biosecurity is acted upon at the farm level will also be discussed with a focus on those individuals intrinsically linked to biosecurity as a means of safeguarding their financial futures through trade and the ability to operate within a growing and dynamic industry.

2.2.2 Implementing biosecurity

This section will introduce the development and implementation of national biosecurity policies. The approaches and international organisations are responsible for developing the direction and basis for biosecurity practices in the UK and other nations. The overarching dimension of biosecurity allows for a degree of flexibility within national policy construction as nations differ in identifying and ranking threats to biological life within their borders. Within UK agriculture systems, biosecurity success is equated to limiting movement of biological life categorised as unwanted. This limitation applies to the potential spread from host bodies to regional and national borders.

The development of the policy and regulatory framework for biosecurity in the UK has emerged from a long and disjointed history of agriculture interventions, principally around animal health. The recent decades have seen a succession of high-profile disease outbreaks, including bovine spongiform encephalopathy (BSE) to foot-and-mouth disease (FMD) and the ever-present problem of bovine tuberculosis, Highly Pathogenic Avian Influenza and more recently, African Swine Fever. Animal diseases have far-reaching political, economic and public health consequences (Donaldson, 2013:63). Currently, the regulatory frameworks operating within the UK comply with the OIE and EU legislation. In the UK's case, the primary policy relating to disease prevention and control is the Animal Health Act 1981 and its subsequent amendments. The act is the responsibility of DEFRA. DEFRA, in conjunction with several executive agencies and local councils, are tasked with implementing the act. Most notably in respect to aquaculture in England and Wales is Cefas and the FHI.

In many ways, biosecurity is merely a set of narratives, technologies, and practices that are implemented to address emerging disease and its pathways (Hinchliffe, et al., 2013) while preventing disease incursion and exposure of humans, animals and plants to infectious pathogens (Koblentz, 2010). Scott (1998) explores this shift in status as flora and fauna are seen for their utilitarian or market value while competing species are stigmatised; the divergence between "crops" and "weeds", or valued animals as "game" and "livestock" while problematic species that may compete with or prey on them as "predators" or "pests". Effectively biosecurity approaches in agriculture have traditionally focused on what can be described by Brown as 'will to closure' Brown (2010) a concept built on efforts to make life safe as informed by 'veterinary and health institutions once germ theory established the mechanisms for contagion as largely a matter of microbiological transmission and of the absence or presence of disease agents or pathogens' (Hinchliffe et al., 2013:533). This approach to closure is effectively understood through the concepts of sanitation, surveillance and organisational integration.

Sanitation

Sanitation in the context of biosecurity is the cleansing of the landscape from unwanted infections. Sanitation is significant within the UK as it has been primarily experienced during the bovine spongiform encephalopathy (BSE) and foot-and-mouth outbreaks in recent decades. Suspected cases were culled, and access to the countryside was restricted in an attempt to stifle the disease's ability to spread. This style of segregation is by no means a new initiative as leper colonies in ancient Roman times are a testimony to this intervention style. Sanitation has evolved to move the responsibility for implementing disease prevention measures from the state and instead firmly place the producer at the epicentre of biosecurity. In practice, sanitation involves implementing barrier systems key to separating the protected life within the farm from the unregulated life outside. The practicality of such measures can be brought into question. Although a farmer may control the movements of farmed poultry, there is an absence of control of biological life outside the farm confines, including the migratory pathways of bird species, breaches by predators and escapes.

Surveillance

Complementing efforts to segregate and sanitise is the presence of surveillance. Where policy exists to sanitise, there is a requirement for a level of surveillance to supplement and reinforce sanitation measures. Surveillance provides a network of reassurance for those operating within the realms of an industry, that the life which is circulating is disease-free, in essence, surveillance acts as verification and offers traders assurances on the quality of product as one free from disease. This approach focuses biosecurity on 'disease incursion and containment of livestock production systems and beyond this the dangers to public health' (Hinchliffe et al., 2013:534). Active surveillance facilitates accurate and timely responses to disease outbreak events. In the event of a disease outbreak, infected areas can be identified along with trade or movement links between an infected area and another area to effectively establish quarantine zones.

Organisational Integration

Completing the biosecurity trifecta of closure is organisational integration. The growing trend in biosecurity has seen a move towards 'standardisation and uniformity of practices; that is, to reduce the diversity of practice and environments through a strategy of organisational integration' (Hinchliffe et al., 2013:534). This approach favours the larger producers who are capable of streamlining production practices to meet the set requirements.

2.2.3 Beyond closure

Together sanitation, surveillance and organisational integration incorporate a will to close. Questions can be asked regarding the suitability and viability of this closure approach to biosecurity. Does it transfer across a variety of forms of production facilities? Can it be monitored to a degree where assurances can be granted?

There exists a growing argument against the effectiveness of this method of closure. Hinchliffe et al., (2013) advocate that this approach to biosecurity is problematic. It is their understanding that 'borders are always also contact points; they join worlds together and act as conduits as well as barriers. Indeed, the permeability of walls is a requirement for life to live, to circulate. Second, enclosing life is no guarantee of safety. That which is enclosed may be subject to threats from within. Finally, the regulation of inevitable border crossings and circulations through surveillance and statistical mapping is underpinned by a geometry of disease outbreaks that have pathogens crossing into populations rather than being already present' (2013:535). In this way, framing biosecurity calls for a shift away from the classical sense of biosecurity borders to one of borderlands (Hinchliffe et al., (2013). This conceptual shift from spatial thinking - a geometrical disease network approach to one that emphasises the very intra-actions that facilitate disease is of considerable significance. This new conceptual approach to biosecurity is known as disease topologies. The reformulation in how we think about disease shifts the established reality of 'proximity, presence and distance' for a more nuanced set of 'topological tipping points' (2013:538) which examines the intensity of these moments where the topological handkerchief is crumpled together and stuffed in one's pocket (Serres and Latour, 1995; Latham, 2002).

2.2.4 International drivers of biosecurity

Over the past few decades, there have been several disease outbreak events that have dramatically impacted the UK agriculture industry. These events include Bovine Spongiform Encephalopathy (BSE) Foot and Mouth (FMD) and the ever-present threat of Bovine Tuberculosis. These outbreaks and the ongoing threat posed to animal life and the social, political and economic futures of those connected to the industry. The UK biosecurity framework is a complex network of executive agencies and governmental compromises of the Food Standard Authority (FSA), DEFRA, the Scottish Government and Northern Irish assembly. Donaldson (2013) highlights the complexity of the UK biosecurity field. Looking to the future uncertainty relating to the effect Brexit will have on UK biosecurity remains unclear. The UK and other European countries are members of OIE, and currently, the European Union strives to adhere to the OIE requirements, thus boosting the opportunities for trade within the single market. It is unclear what trade opportunities will exist upon the UK's exit from the single market. However, it is reasonable to suggest the UK's continued membership of the OIE and its efforts to implement the OIE's requirements will be strategically important in efforts to maintain trade options in the face of growing uncertainty. EU regulations require member states to draft National Control Plans. The plans offer a more comprehensive approach to biosecurity and food security than some national integrated approaches.

For biosecurity to be effective, a concerted effort is required from a range of stakeholders. Donaldson (2013) argues that biosecurity is a process of dealing with the risk of issues before they manifest themselves. This focus on what could happen is particularly noteworthy in the context of biosecurity, and its effect on human, animal and plant life and the emphasis on prevention, the suitability of risk-based approaches to disease management becomes evident. Waage and Mumford (2008) are advocates of consolidation in risk analysis in the UK. Their perspective requires a reimagination of traditional forms of biosecurity, drawing together animal and plant measures to focus attention on 'desired outcome rather than the action to consider different routes of reaching it' (Donaldson, 20013:67). As has been explored, the conventional approach to biosecurity seeks to restrict the entry of undesirable life into a country, region or integrated production system, while Wage and Mumford (2008) would argue the focus of biosecurity should primarily be on developing systems that are resistant to disease threats, rather than a never-ending quest to restrict border controls and physical entry points. This leads to Donaldson's (2008:1556) argument that 'biosecurity is not about managing animal diseases themselves; it is concerned with animal disease risk'. The biosecurity practices detailed above aim to reduce the likelihood of a given population becoming infected at reducing risk in this (limited but pertinent) sense.

How biosecurity is implemented in the UK is closely aligned with the international frameworks of the European Union and the World Trade organisation (MacLeod et al., 2010), in some cases, increased measures may be implemented that reflects the ability of the island geography of the UK to protect against threats. At the time of writing, the EU regulations which form the pillars that support the UK biosecurity framework are as follows:

- Regulation (EU) 2016/429 on transmissible animal diseases
- Regulation (EU) 2016/2031 on protective measures against pests of plants
- EU Regulation 1143/2014 on Invasive Alien Species

- Aquatic Animal Health (England and Wales) Regulations 2009

This trifecta of EU legislation forms the pillars of biosecurity across all forms of animal and plant-based agriculture within member states, as national-level legislation rarely diverges from the objectives of the overarching EU legislation.

2.2.5 Key aquaculture legislation (England and Wales)

With direct reference to biosecurity in aquaculture systems, the EU has implemented a horizontal framework for the 'prevention, early detection, rapid eradication, and management of invasive alien species across the whole EU', this is achieved through Regulation 1143/2014 on invasive alien species. On a national level, this EU legislation is manifested in the Aquatic Animal Health (England and Wales) Regulations 2009. This piece of legislation identifies the invasive/non-native disease species for fish, crustaceans and molluscs in England and Wales. These non-native diseases are often referred to as listed or notifiable diseases. Additionally, the current disease status of each is listed in the legislation. In the case of fish, the notifiable diseases and their current status are presented in table 2.1.

Table 2.1 Fish Disease Status for England and Wales

Notifiable Disease	Disease Status
Bacterial kidney disease (BKD)	Not recognised as free. National controls for the disease only
Epizootic haematopoietic necrosis (EHN)	Declared free
Gyrodactylus salaris (GS)	Declared free
Infectious haematopoietic necrosis (IHN)	Declared free
Infectious salmon anaemia (ISA)	Declared free
Koi herpesvirus disease (KHV)	Undetermined
Spring viraemia of carp (SVC)	Declared free except control area Arden Lake
Viral haemorrhagic septicaemia (VHS)	Declared free

Table 2.1 illustrates the high degree of biosecurity currently in operation in England and Wales within the aquaculture (finfish) industry as all but one disease, Bacterial kidney disease (BKD), is designated with the gold standard declared free status, or in the case of the carp disease, Koi herpesvirus declared undetermined.

Caution must be exercised to resist as Maye et al., argue ‘an equation which associates neoliberalism with openness and biosecurity with closure is too simplistic, failing to recognise the tensions and intermingling with each domain, and their coconstitution as a hybrid form of neoliberal rule’ (2012:163). Questions emerge on the future of biosecurity as the UK exits the European Union and new trade agreements are entered into. Currently, risk-based analysis can be viewed as maintaining plant and animal health. It is argued by Maye et al., that it is important ‘primarily in terms of facilitating trade within the EU Single Market’ (2012:162). Uncertainty exists in the future of biosecurity implementation as we need to address the complexity of national and international politics.

2.3 Rapid Evidence Review – Biosecurity & freshwater finfish Aquaculture

It is of critical importance to understand the current industry-specific academic literature. The rapid evidence review was implemented to develop more insight into the current academic knowledge of biosecurity challenges within aquaculture. The rapid evidence review was carried out on the currently available scientific research relating to biosecurity in freshwater finfish aquaculture. This strategy has proved valuable insights into biosecurity and infectious disease in other aquaculture systems such as the Bangladesh shrimp industry (Garza et al., 2019). The method used to complete the rapid evidence review is described in detail in Chapter 3 (3.3.2).

In summary, a total of 69 publications were identified as conforming to the second stage of screening. A third and final manual screening was carried out to identify any publications that engaged with biosecurity practices as opposed to the clinical diagnosis of pathogen development in salmonid diseases. This approach yielded a total of 38 publications of interest. The identified publications will now be examined to provide greater context to biosecurity with the industry.

2.3.1 Reviewed literature

Of the available academic literature, the dominant characteristic present was the focus on the biological understanding of disease and disease pathogens. In contrast, publications relating to biosecurity management practices and efforts to limit the spread of specific pathogens were limited to a small number of publications that examined risk-based surveillance strategies for rainbow trout farming. In addition, the most widely referenced diseases in the literature were unsurprisingly ERM and VHS. These conditions pose significant economic challenges to the aquaculture industry and therefore account for the focus of academic research. A notable trend in the literature was the rise in research on diet and the use of probiotics in aquaculture as a method for pre-empting the common fish health challenges. The literature on trout aquaculture will now be introduced by theme, 1) Disease, surveillance and vaccination; 2) Diet and the role of probiotics; 3) Alternative treatment innovation.

2.3.2 Disease, Surveillance, and Vaccination

Of the reviewed literature, the key disease surveillance strategy that emerges is a risk-based surveillance modelling approach. This strategy has been demonstrated as an effective approach that can be effectively applied to rank fish farms according to their risk of infection to VHS (Oidtmann, et al., 2014). The applicability of the surveillance model to a non-native and notifiable disease such as VHS that posses the potential for serious financial impact. Risk-based surveillance is identified as a strategy to contend with complex networks of physical relationships between catchment areas, hosts and trade links. The risks identified are sorted into five distinct avenues: (1) Live fish and egg movements; (2) Exposure via water; (3) On-site processing; (4) Short-distance mechanical transmission; (5) Distance-independent mechanical transmission. Although these avenues of disease spread are presented in relation to VHS, they apply to other notable aquatic diseases prevalent in trout aquaculture. This applicability provides a valuable tool for conceptualising the spread of disease in aquaculture environments, allowing fish farmers to consider their own farm site's vulnerabilities. The arguments for this style of risk-based biosecurity are attributed to the practicality of surveillance and limited financial and human resources and will be explored in greater depth in Chapter 7.

Vennerström et al., (2017) argue that syndromic surveillance, a style of surveillance that ‘attempts to identify illness clusters early, before diagnoses are confirmed and reported… and to mobilise a rapid response’ (Henning, 2004), is a more consistent detection method than active surveillance. In the case of Vennerström et al., (2017) it was implemented by processing samples for analysis when any clinical signs of infectious disease were present in a water body below a designated temperature. Muniesa et al., (2018) similarly argue that the use of syndromic surveillance and participatory epidemiology can provide real-time alerts and early warnings of disease. ‘The platform can be used by owners or those responsible for farms who wish to collaborate in the development of this system of epidemiological alert and to prevent future diseases that cause incalculable losses in the sector’ (2018:370). Such an alert system may have value if a collective mass of users adopts the system forming an invisible network of information transfer between farm sites. Oidtmann et al., (2011) make the argument that a semi-quantitative model of ranking can be effective in identifying the risk of exposure and the spread of a specified pathogen. In this model's development, the authors utilised a series of workshops to identify and rank the potential ingress points on farms. Not only were ingress points uncovered, but the entire interconnectivity of the industry was brought to the fore. The development of this modelling toolkit provides a transparent approach to ranking farms with regards to pathogen transmission risks in the context of wider biosecurity challenges. This risk-based ranking system underpins the risk-based surveillance model operating in the English and Welsh aquaculture industry.

Publications that provided a specific focus on disease are limited to parasitic infections and the economically significant VHS, ERM and the emergent Puffy Skin disease. Studies that presented evidence on parasitic infections such as the work of Jørgensen et al., (2009) and Barber (2007) argue that it is important to focus on the interrelationships between behaviour and fish welfare, how parasites and disease impact the hosts. The natural occurring practices of fish are altered in the confinements of modern aquaculture settings they potentially lose the ability to perform natural practices to mitigate the exposure to disease parasites, in particular, e.g. moving between fresh and saltwater. Three reasons are suggested: natural practices in the wild mitigate fish exposure to parasites (Barber, 2007). Firstly, in a controlled artificial environment, the fish's agency to utilise such natural behaviour is reduced, yet the threat of exposure remains the same or potentially greater due to the risk of horizontal transmission between tank or pond mates. Fish that are stocked in ponds or raceways are subjected to exposure of flow-through water. This water source is constant, usually a river or an upstream spring or a borehole. The fish have lost their ability to expand their natural range to improved water quality locations and are now subjected to the inflow pipe that feeds the farm. Secondly, the exacerbation of welfare concerns for fish in aquaculture systems afflicted by parasites and expressing clinical signs in natural behaviour changes. Finally, the ability to identify parasite-induced behaviour changes. These findings on the interrelationship between hosts and diseases present important information to an industry that wishes to reduce disease's financial impact on producers.

Kinnula et al., (2017) suggest that a case can be made that higher resource levels present in water bodies can promote virulence in bacterial fish diseases that can be environmentally transmitted. 'The increase in virulence could not be exhaustively explained by the increased dose under higher nutrient supply, suggesting virulence factor activation. In aquaculture settings, the accumulation of organic material in rearing units can locally increase water nutrient concentration and therefore increase disease risk as a response to elevated bacterial density and virulence factor activation. Our results highlight the role of increased nutrients in outside-host environment as a selective agent for higher virulence and faster evolutionary rate in opportunistic pathogens.' Such findings are of value to the aquaculture sites in England and Wales that operate a mixture of pond construction and water circulation or flow-through systems; with each farm balancing the available volume of water flowing through the site with the stocking density required to ensure the profitability of the aquaculture business. Kinnula et al., (2017) research allow questions to be asked on the best practice guidelines for stocking density across different site constructions as fish farmers carry out the precarious act of balancing fish health and profitability, there is the need for more research on this important issue.

Of the aquatic diseases relevant to the trout industry of England and Wales, perhaps the most notable is VHS. The importance of VHS to the trout industry and the severity of the impact of an outbreak event is reflected by the focus of Sharifnia and Kazemi (2008); Cieslak, et al., (2016) and Oidtmann, et al., (2014). This focus on VHS is distinctly welcomed in the context of this research. There is little doubt that the VHS outbreak event in 2006 has influenced research interest in this disease, as this VHS outbreak represents the last instance of incursion by a non-native disease case documented by Oidtmann, et al., (2014). In addition to the focus on VHS, there is growing evidence of interest in emergent disease threats. Peeler et al., (2014) and Maddocks, et al., (2015) are examples of this trend as their work examines Puffy Skin disease's emergent disease threat. Since the initial emergence of the Puffy Skin disease in 2002 (England), it had persisted at a low rate until 2006, when the cases increased substantially (Peeler, et al., (2014). As the disease has only been reported in rainbow trout and has the potential to increase farm costs while reducing profitability due to culling and carcass downgrading the disease is of significant importance to the industry. What is notably in the case of Puffy Skin disease, the requirement for further investigation is apparent, particularly in the identification of the disease's aetiology and practices by which the disease is managed.

It is worthy of note that endemic diseases were represented in the review. Endemic diseases are frequently occurring and common to the industry or a geographical location. ERM is a notable disease that has acquired researchers' attention and frequently occurs during conversations with fish farmers. A number of publications were identified that focus on the disease and vaccination strategies surrounding ERM on aquaculture businesses. Tobback et al., (2007) provide the definitive review of the agent (Yersini ruckeri) and the disease it causes (ERM), Huang et al., (2015) document the presence of ERM in northwest Germany and the dissemination of the infection between the farms. The authors argue for the importance of trading as a means of disease dissemination between, in this case, twelve different rainbow trout hatcheries and the movement and trade of stock through this network. This argument echoes Oidtmann et al., (2011) calls for a greater focus on the movement of live fish concerning disease transmission between aquaculture sites. ERM is an interesting example as a vaccination protocol for the disease is in operation across the industry, providing a key biosecurity practice to examine in more detail. Prophylactic measures (vaccination) based on stimulation of the immune systems of individual fish have emerged since 1976. Gudding and Van Muiswinkel (2013) present the history of science-based disease vaccination as a form of prevention from the initial vaccine development for yersiniosis in salmonids. Vaccination strategies are further discussed by LaPatra et al., (2015) who evaluates the dual nasal delivery of IHN and ERM vaccines., Schmidt et al., (2016) introduce the role of immersion vaccination of fry during handling and transportation to mitigate one of the biggest problems to fish health in ERM. ERM and the real-world impact is documented through the international example of Spain by Fouz et al., (2006) as an emergent form of the disease has been documented in cultured or farmed trout. These populations have been vaccinated with commercial ERM vaccines. Additionally, Zorriehzahra et al., (2017) provide the case of the ERM and the disease history in Iran. The prominence of ERM and the available vaccine in the literature provides an example of an economically important disease being effectively mitigated through the development of a vaccine that is now in widespread use.

What remains undocumented is the social and logistical challenges faced by fish farmers who are considering the implementation of a vaccination strategy. There is a financial burden on the producer and the requirement for both the time and availability of skilled labour to carry out the practice of vaccinating a population of fish. Further research into such field-based challenges can effectively contribute to research on vaccination levels across the industry.

2.3.3 Diet and the Role of Probiotics

Research into fish diets and the benefits of probiotics is an emergent research trend, with a clear economic incentive and supported by feed developers across aquaculture yet retaining a role in fish health. Hoseinifar et al., (2015) argue that there is a distinct relationship between fish nutrition and fish health. Their review identifies the growing role of functional dietary supplements in fish health. The presence of ubiquitous bacteria causing haemorrhagic septicaemia, fin rot, soft tissue rot and furunculosis pose significant problems for fish farmers due to major mortality events and research into this area suggest diet and probiotics can be of assistance to fish farmers. A new focus on alternative approaches to controlling disease problems has emerged through the work of Fečkaninová et al., (2017). Burbank et al., (2011) introduce the example of Cold Water disease, or as it is more commonly referred to as RTFS. They suggest the potential for strains of probiotics to provide benefit and an alternative strategy for managing the causative agent in RTFS (Flavobacterium pyschrophilum). The advantages of such probiotic treatments are highlighted by Pérez-Sánchez et al., (2018) who argue that although great development and intensification of production has seen the aquaculture industry develop over the past three decades, the industry is now being challenged by infectious diseases that are showing signs of antibiotic resistance. The authors argue for the urgent requirement for more environmentally friendly approaches. The authors stress the need to understand better how fish and shellfish immune systems generally respond to certain microbiota components (e.g., probiotics, postbiotics, etc.). It is anticipated that this will provide a basis for targeted manipulation of the microbial composition, which could be used to design adequate strategies for disease prevention and treatment.

Other dietary additions are under consideration and testing, Sealey et al., (2007) evaluates the ability of partially autolysed yeast and Grobiotic-A to improve diseases resistance in rainbow trout. The results suggest improvements in the survival of rainbow trout exposed to the partially autolyzed yeast or Grobiotic-A under experimental challenge with IHNV. At the same time, Uluköy et al., (2017) examine the addition of kefir in commercial pellets. The authors argue that their work demonstrates that ‘kefir-fed fish had an increase in measured nonspecific immune parameters. The challenged fish fed with Kefir-supplemented diet showed a better survival rate against Lactococcus garvieae and in additions reduced mortality significantly against L. garvieae. As feeding provides the most frequent interaction between fish farmers and fish, the development and growing importance of probiotics provides evidence that preventative and precautionary measures are being considered, developed and implemented in an effort to boost overall fish health in conjunction with disease resistance and the ability of the fish to thrive.

2.3.4 Alternative Treatment Innovation

Alternative treatments exist in the form of the semi-continuously addition of peracetic acid to flow through fish farms as examined by Pedersen and Henriksen (2017) as a potential for the replacement of formalin treatments are of particular importance to the sustainability of future farming practices and gaining the attention of researchers. How effective these strategies can be on commercial farms is yet to be determined. The problem of stress for farmers of rainbow trout is a constant feature. Undoubtedly one of the primary causes of fish stress in aquaculture is the practice of handling and transporting live fish. Tacchi et al., (2015) examine the effects of this transportation stress on farmed fish and the adoption of salt during transportation to mitigate the changes to rainbow trout skin who experience stress brought on by the conditions of transportation. The industry sees salt treatments as an alternative for the use of formalin. The use of formalin treatment baths are widespread in the industry as one of the primary methods used to combat parasitic infections Ispir et al., (2017) documents this practice and although highly effective in this task, formalin is shown to be problematic for whole-body health of the fish. Ispir et al., (ibid) argue that acute formalin inhalation may cause oxidative stress and, thus, some secondary toxic effects in whole-body, while demonstrating carcinogenic properties in other industrial settings, thus leading to efforts to withdraw the use of formalin from the industry.

2.3.5 Knowledge gap

The rapid evidence review has brought to the fore the three topics that dominate the aquaculture industry: disease, surveillance and vaccination; diet and the role of probiotics; alternative treatment innovation. What is conspicuously absent from these research trends is literature that examines the socio-economic factors that can act as drivers for biosecurity issues. This thesis seeks to contribute to this knowledge gap by developing these socio-economic factors.

2.4 Taking practices seriously

This section will establish how and why biosecurity implementation calls for a social science approach that takes practices, rather than behaviours, seriously. By approaching the question of doing biosecurity in aquaculture through practice theory, it offers fresh insight into what drives biosecurity at farm level.

The previous sections have explored the complexity of what biosecurity is and what it means to carry out biosecurity in a manner that is implementable and fit for purpose. What is now required is a sense for why social science and indeed one that takes practices, rather than behaviours seriously, is called for. To effectively understand how biosecurity is practised at farm levels across an industry like freshwater aquaculture, it is essential to know how a practice operates across space and time.

Social science research has the flexibility of allowing researchers to approach a problem or situation from several different theoretical perspectives. The choice of approach relies on selecting a theoretical framework that will prove advantageous to the researcher attempting to answer the research question and the expertise and skill set of the researcher undertaking the project.

Although practice theory was chosen in the case of this project, alternative approaches may have been utilised. Behaviour change is one such approach that has been in vogue during the past decade for policymakers in several countries, including the United States of America and the United Kingdom. Behaviour change is on face value the key objective for policymakers, as they aim to adjust the patterns of society to correspond with a particular policy focus, the reduction of smoking to alleviate health care expense; reduction in personal car travel in a bid to tackle climate change and city pollution levels. In an attempt at realising a macro-level goal, policymakers may consider what they can do to adjust or completely change the actions of individual members of wider society.

Behaviour change, taken at face value, may miss the important networks and elements involved in a day to day process. In essence, social practice theory and behaviour change are on opposing sides of academic debate. Shove et al., (2012) recognise the popularity of behaviour change works such as Thaler and Sunstein (2009) and Ajzen (1991) but argue against several points relating to the understanding of the basis of action, processes of change, positioning policy and transferable lessons as illustrated in Table 2.2. In the following comparison, these approaches this research argues the case for the more complex and in-depth approach to theories of practice for this research project.

Table 2.2 Behaviour & Practice; Points of Difference (Shove et al., 2012:143)

	Theories of behaviour	Theories of practice
Basis of action	Individual choice	Shared, social convention
Processes of change	Casual	Emergent
Positioning policy	External influence on factors and drivers of behaviour	Embedded in the systems of practice it seeks to influence
Transferable lessons	Clear: based on universal laws	Limited by historical, cultural specificity

Basis of action

The individual is the key in behaviour approaches, while external social norms or indeed, context may be applied to the individual, they are merely external pressures. According to Shove et al., (2012:144), this rhetoric of driving factors does not represent meaning, practical knowledge and competence that come together and are reproduced via the process of doing.

Processes of change

There is a divergence in how change is conceptualised across behaviour and practice approaches. Shove et al., (2012) suggests that behaviour relies on 'cause –and0effect' type explanations for the very behaviour in question. In comparison, the idea to seriously consider 'path dependence' as a means to explain outcomes through the tracing of events that a practice creates. Indeed there is the acknowledgement that the very unit of analysis to change and alter over time and its meaning. This conflicts with the fixed nature of identity and time in theories of variance (Geels and Schot, 2010)

Positioning policy

Popular among behaviour approaches are acts of intervening in the form of ‘carrots, sticks and sermons’ as a way to enable individuals to make better decisions themselves (Collins et al., 2003). It can be argued that practices are as Shove et al., (2012:144) describes ‘practices reproduced in any one society are outcomes of complex, essentially emergent processes over which no single actor has control, we have to think again about the actual potential role of public policy’. We are better able to approach the question of position policy as a series of process centred events intrinsically linked to the context and the nature of the practice in question. It is beneficial to view practices as an embedded system.

Transferable lessons

Behavioural approaches anticipate that learning can be achieved from examples in different countries and entirely unrelated examples of life. This approach believes ‘behaviours are outcomes of identifiable factors that it is, therefore, possible to identify, quantify and evaluate the merits of behaviour change techniques’ (Shove et al., 2012:146). Theories of practice bring to the fore cultural and historical reasoning to make sense of what people do through a reflection of how practices are positioned amongst themselves and the accumulation of meaning, materiality and competence involved.

Shove (2010) recognises the attractive nature of an Attitude’, ‘Behaviour’ and ‘Choice’ (ABC) approach from a political perspective. The ABC approach places the responsibility of change squarely on the shoulders of the individual. This focus on the individual repositions the focus from a centralised governance structure to the actions of the individual, therefore effectively shifting the burden of responsibility. Shove (2010) argues that an ABC approach is not sufficient to delve into the more complex social and societal issues with the same conceptual clarity that social practice theory offers. The popularity of behaviour change approaches such as ‘nudge’ (Thaler and Sunstein, 2009) are ill-equipped to investigate complex practices such as biosecurity in aquaculture.

A debate exists on the extent to which governments can or should manipulate the desires and ambitions of individuals by editing their choices (Jones et al., 2011; O'Neill, 2010). What remains a constant in behaviour change literature is the role of choice between pathways that people can take. This sense of choice is further influenced by factors such as attitudes and beliefs hold particular sway. From a policy perspective, this approach attempts to identify and segregate the target populations to customise the appeal to those who are disengaged.

Practice theory for all its conceptual benefits runs into practical problems. Governments would need to move the responsibility from the individual in a behaviour change framework to the collective through an inclusive practice theory approach. Shove et al., acknowledges this potential stumbling block, as governments must shift to "highlighting and exploiting rather than obscuring these roles" (2012:164). Such a shift in direction may be resisted for both policy and political reasons beyond the influence of social science.

2.4.1 Social Practice theory in use

Theories of practice have evolved through the work of Wittgenstein into a concept that provides social scientists and policymakers with a valuable conceptual tool that can be applied to a wide range of human practices. To date, practice theory has been applied to a diverse selection of research strands including neuroscience (Lizardo, 2007), climate change policy and domestic consumption debates (Shove, 2010), transport studies (Barr, 2015) among others. This non-deterministic approach to human actions is described by Schatzki as a bundle of activities, a form of organised nexus of individual actions (2002:71). Reckwitz (2002) offers a more precise interpretation of practice which provides a useful starting point. Reckwitz argues that a distinction must be made between a 'practice' and 'practices'. The former (practice) describes the entirety of human action in contrast to theory and mere thinking. In comparison, Reckwitz describes a 'practices' within the realm of the theory of social practices as a "routinized type of behaviour which consists of several elements, interconnected to one other: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge" (2002: 249).

A central component of social practices is that of 'know-how'. Schatzki (2002) draws his audience away from the term and instead focuses on 'practical understanding'. This understanding is rooted in the work of Bourdieu (1984) and Giddens (1984) in so far as 'having a feeling for the game'. For Schatzki, the grasping of such practical consciousness is in the form of a skill or capacity that underlies activity. This approach involves not determining what makes sense for people to do. What is important to consider is the role of practices in the establishment of social orders. For Schatzki, social orders are 'largely' established in practices and in-turn, practices establish particular arrangements. In this way, theories of social practice have developed as a less individualistic account of behaviour.

Practice theory presents a more coherent, holistic and rational account of behaviour than the individualism of linear models of behavioural correction such as Ajzen's (1991) 'theory of planned behaviour' and Fishbein and Ajzen's (1975) 'theory of reasoned action'. Hargreaves argues that practice theory offers a unique approach, 'the focus is no longer on the individuals' attitudes, behaviours and choices, but instead on how practices form, how they are reproduced, maintained, stabilised, challenged and ultimately killed-off; on how practices recruit practitioners to maintain and strengthen them through continued performance, and how such practitioners may be encouraged to defect to more sustainable practices (2011:84). Unfortunately, 'there is no unified practice approach' (Schatzki, 2001:2), with conflict on 'defining exactly what a practice is' (Hargreaves, 2011:83). Perhaps the most helpful approach to conceptually applying practice theory is Reckwitz (2002) approaches and Shove and Pantzar (2005) who examine the many components or as they will be referred to 'elements' that make up a practice. The following sections will expand on elements and the connections that emerge, maintain and break between elements.

2.4.2 Elements: the foundations of practices

Essential to understanding practices, one must consider the role of the active elements. Elements or components form the structure that makes up and facilitates the emergence and continuation of a practice. There are three elements:

1) *Competence,* refers to the know-how involved in doing a practice. For example, this is physical and mental ability to coordinate one's body to balance on a bicycle and the capacity to operate the pedals, handlebars and gear mechanisms, along with the knowledge of the rules of the road. Giddens (1984) understands the concept as a combination of practical consciousness and deliberately cultivated skill. Shove et al., (2012) applies the term *competences* to capture the sense of knowledge and skills required. Competence can be taught and developed over time through increased knowledge and specific skill development. However, it is also possible that specific knowledge and skills may deteriorate over time and generations as practices must circulate to persist beyond initial emergence.

2) *Meaning,* refers to the underlying reasoning as to why one social practice emerge ahead of another competing practice? This idea of reasoning is highlighted by Reckwitz (2002), who equates why with *meaning*. Is there a key identifying reason driving the practice for the individual practitioner or indeed a socially constructed meaning that exists? Individual and collective social meanings vary from individual to individual, group to group over place and time. They are ever-changing and continuously adjusting to the wider world. Continuing with our cycling example, why does one cycle? Cycling is a multi-meaning practice. It is a form of low carbon transport, a leisure activity, or even a form of health promotion. It is argued by Schatzki (2010) that practices have a history and a setting for that individual and more broadly for society.

3) *Materials*, comprises of objects and bodies involved in a practice. Schatzki (2002) highlighted the interwoven connection between practices and objects. For a practice to be carried out, it requires physical equipment. Shove et al., (2012) includes the body along with tools, hardware, objects and infrastructure within the umbrella of materials. Returning to our example of cycling, the bicycle and its parts (wheels, cables and gears) and complete the elemental trifecta of cycling by facilitating the competence and meaning of a would-be user to carry out a cycle.

Utilising these three elements allows the theory to be applied to a wide variety of set-ups. In the context of this research biosecurity and disease management in aquaculture is the focus. Applying this conceptual framework to issues of biosecurity practices will allow fresh insights into how the industry addresses such issues in practice. Schatzki (1993:96) argues that a practice is a collection of considerations that recursively inform how people act. With this in mind, how do fish farmers engage with issues of biosecurity while balancing the economic, labour, market and environmental factors at play within the industry? Indeed, such considerations and their provenance, embeddedness, and reproduction are of considerable importance as we examine biosecurity within the industry. These questions highlight Schatzki's understanding that practices are complex and often crisscross and interweave to form densely interwoven mats (2002:87). The work of Shove et al., (2012) seeks to distil the earlier work of Reckwitz (2002) and other key authors [Giddens (1984), Bourdieu (2012) Røpke (2009) and Schatzki (1996)] to construct a more adaptable approach to elements that can be applied by policymakers struggling to grasp complex and nuanced issues. In essence, Shove et al., (2012) argue that social practice theory seeks to unpack the *how, why* and *what* of everyday practices to assist policy development. It is in this context that practices of biosecurity in aquaculture can be examined.

2.4.3 Links

We are now secure in the knowledge that for social practice to exist; competence, materials and meanings are required. These three elements must be present and connected for the practice to occur. It is here that social practice theory reveals its worth to social science research. Applying this theoretical framework to the opening vignette of this chapter we are introduced to the material in the form the purpose-made table, the injection guns and of course, the trusted and performing vaccine itself. The competence exists within the farmers' capabilities to manage the skill set of safely vaccinating the fish and their trained knowledge in identifying the point in the lifecycle of the fish that enables the most significant positive impact on their stock. There is an overlap between competence and meaning in this example as the rationale behind vaccination is linked to both the farmer's motivation to secure the health of the stock and the farmer's economic stability as a business. The threat of the economic hardships they may endure if the disease becomes present on their farm, is balanced with the broader network of actors involved in the aquaculture industry from processors contracts that require a reliable supply of finished fish to the watchful eye of industry and regulator audits and inspection seeking to safeguard animal welfare and biosecurity requirements. These factors come together in the conscious decision-making process as to the undertaking or not of a vaccination program.

It is important to acknowledge that by merely co-existing, elements do not contribute to a practice. Instead, they provide the potential for linkages to form. It is the linkages between these elements that facilitate and maintain a practice. Furthermore, the balance between competence, meaning and material is forever in flux. Shove et al., (2012) offer the historical account of driving to underpin the examination on how practices emerge. In the case of driving a car, many of the elements bound together in the practice of driving have existed long before the emergence of automobile transportation.

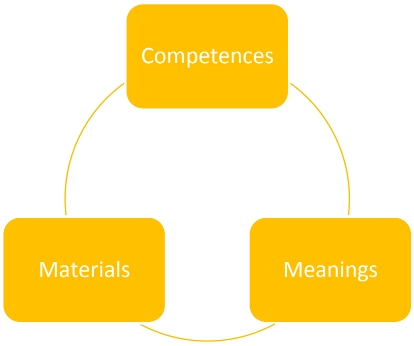

Fig 1 Linking elements to form a practice

The *materiality* evolved through horse and carriage technology, the internal combustion engine and established transport routes. The *meaning* is evident in the requirement to transport oneself or goods between two locations. In many cases, early automobiles were unreliable and required a high degree of *competence* to operate, maintain and repair, as a driver at the turn of the 19th century as explained by Borg to become “a complete master of the art of driving a self-propelled vehicle... you must, in the first place, be a good mechanic” (1999:804). This balance between a material shortfall in reliability being supplemented by high levels of competence in the people carrying the practice allowed driving as a practice to exist and develop over time. Like all practices, this has evolved with the balance between elements shifting and changing as automobiles' material reliability has dramatically increased to a point where competence levels of maintenance and repair are dramatically lower. Yet, the practice is still maintained and carried through time. Shove et al., (2012:27) acknowledge the importance of specific configurations of materiality and competence and how it is now evident that practitioners of driving currently lack the competence to operate an early automobile. Borg (2007) supports this fluidity of competence by referencing earlier animal husbandry know-how, a key component of the caring for the horse, in a society dominated by the horse and cart as a transportation means. The changing dynamics tracks the emergence of service stations and garages in place of farrier yards and blacksmiths, to an extent the competence of such traditional crafts have been marginalised and subsumed by the requirement of mechanics. This is an important consideration when examining the likelihood of a physically demanding practice to recruit new individuals, new carriers. Worthy of note are the levels of continuity at play as elements associated with one practice can be carried forward to form links and establish new practices that reflect both the location and time, for example, the movement from horsedrawn carriages to early motor vehicles.

It is also possible for practices to work in synchronisation with others to realise a larger goal. Synchronization suggests more than just the independent nature of practices but rather the co-dependence of individual practices to work together in a complex order, as illustrated by Hutchins' (1995) example of docking a large ship or the biosecurity of an industry against the threat of a notifiable disease outbreak. The interaction between practices can be categorised in three forms, 1) Proto-practices, these are elements which exist but are currently not linked; 2) Practices, in this instance the elements have formed links which is sustaining the practice; 3) Ex-practices, are arrangments of elements which are no longer linked. It should be noted that the three forms are not linear, rather they are ongoing interactions of active elements with the linkage between each element of paramount importance. Approaching the formation and disintegration of practices in this element based approach can illuminate a practice's evolution through the constant adaption within its composing elements.

Shove et al., (2012) acknowledge the depth of meaning and highlight the dynamic relationship between participants' status and the meaning they apply to a practice. This serves to locate them within both a societal and cultural structure. Meanings may emerge and diverge over time. This is perhaps a significant advantage of theories of social practice. There is flexibility and understanding that adjustments may occur between the balance of elements over time. Rather than attempting to take learnings from other social practices directly, there is an acknowledgement that competence emerges to develop linkages with meaning and materiality to provide an individual with the possibility of adopting and carrying the practice forward or facilitating the evolution of a practice entirely.

If we acknowledge that elements of materiality and meaning co-evolve, it can be expected that both material and meaning in a practice may change over time. In the case of material, new technological advancements may circulate in the form of affordable, mass-produced vehicles. In the driving example, the meaning has been reconstituted from that of a wealthy and technically minded hobby to a necessary step on the route to an experience. In this sense, material problems and failings now strongly oppose the fluid function of the practice as drivers, for the most part, lack the know-how to rectify such problems. Compared to their previous place as an expected encounter, carriers held the required competence to deal with such issues. A shift has occurred with material element assuming more reliability with the advancement in technology which offsets higher levels of competence. Reckwitz (2002) refers to this relationship as a block. The elements may encounter instances when the balance is distorted. The introduction of a new material element can potentially highlight shortfalls in the competence level of those carrying the practice. These shortfalls may prove decisive, and the practice reemerges in a new form or competence levels increase to restore a balance to the practice over the short term. In this sense, elements are directly moulding each other, this change and integration of competence and material as practices are carried through time as fish farmers do not work in a vacuum, they and indeed the practice they carry is influenced through market forces, politics and regulatory requirements.

2.4.4 Circulation of practices

For a practice to emerge and exist, it requires the co-existence of the aforementioned elements. Yet, this co-existence may not necessarily lead to linkages between elements. Understanding the complexity of the access to, and transport of essential materials is key to understanding the emergence of practices at certain points. The sociotechnical development of new forms of materials allows for the potential of new practices to emerge. Shove et al., (2012:47) highlight the importance of forms of '(co)location, transportation and access’ as being important in the diffusion of material elements. In the case of trout farming, husbandry and biosecurity practices have emerged related to vaccines' development and availability for economically significant diseases and specialised fish feed availability.

In comparison, competence and know-how can circulate or be transported in the same manner as physical materials. Shove et al., notes that know-how moves through ‘abstraction, reversal, lateral migration and cross-practice creep’ (2012:52). This ability to move across practices facilitates the changing nature of know-how. This allows their ability to be stored in reservoirs as they are changed and modified from situation to situation and carrier to carrier to allow them to move across practices, this is important when considering the fluid and evolving nature of know-how. Shove et al., (2012) suggest that the ability to ‘decode’ is not uniform, instead, it is linked to previous practice-based experience, as individuals encounter new experiences and accumulate knowledge and expertise in a manner that is not universal across social groups. For practices to circulate, the availability of competence needs to be as widespread as possible.

2.4.5 Breaking links and re-appropriated material

Society is built around the material relics of previous practices. They are scattered across the landscape, from canals and their role in the transportation of goods to the current example of phone boxes and their relegation through the advent of affordable mobile phones. All is not lost for such material testaments to practice. In many cases, society has re-appropriated the material in new practices. Canal waterways are places of leisure boating while a growing trend has seen automatic external defibrillators replacing phones in public phone boxes. Tracking the evolution versus expiration of practices can prove contentious. Schatzki (2002) argues that when a practice undergoes multiple mutations and is accompanied by continuities in other components, this practice remains constant. This approach helps to contextualise the use or disuse of the materiality within society. Such a focus applies a new lens to objects and infrastructure that has been deemed out of favour or neglected through time.

2.4.6 Interpractice connections

To this point, social practice theory has been discussed by highlighting the connections between elements to form and carry practices. This is not the only form of connection at play as practices themselves have the potential to form connections with one another in the form of 'bundles' a form of loosely linked together through co-location and co-existence, and 'complexes' which appear as more dense or intertwined connections (Shove et al., 2012:82). These connections and inter-practice relations may have effects on individual practices. In cases of co-dependence, practices must undergo constant reproduction if they are to continue to exist. There is also a locational aspect that needs consideration as spatial arrangements underpin many practices. In many ways, aquaculture is such a location-based practice. This localising of practice that allows for bundles to emerge.

2.4.7 Influencing practice

For practices to maintain their existence, they require committed carriers. Without individuals willing to carry practices forward, there is a genuine probability that the practice may fade into obscurity. Shove et al., (2012) pose a series of questions: 1) How are patterns of access and participation structured by policy? 2) How do specific initiatives in policy intersect with the careers of practices and practitioners? 3) How does policymaking shape networks and relationships through which practices are reproduced and carried? These questions are valid throughout any number of scenarios and practices. Regarding access, societal structure and social class persist as fundamental structures to which governments can offer enhanced opportunities to those otherwise unable to experience exposure to the practice in question. Investment in policy must consider that practices do not exist in a vacuum and interventions may promote unintentional flourishment of other practices carried simultaneously to the one that has garnered the policy focus. Strategic investment in a given practice does not guarantee that said practice will capture new and valuable carriers instead, it shapes the elemental distribution of material, meaning and competence that link together and represent the practice.

Social practice theory flips the question from what types and forms of social relationships and engagements will enhance best practice to be adopted but rather what are the links that emerge from the current examples of best practice. This is far from a panacea as practices are never in a stable state but rather constantly in flux and experiencing continued reproduction. This suggests that practice-oriented interventions in policy must be thoughtful in their design and implementation as they consider the relations between practices and those that carry them. Practice theory offers a theoretical foundation and framework to construct and implement programmes and policy to impact change in a systematic manner (Shove et al, 2012:163).

For husbandry and biosecurity practices to exist and persist in aquaculture, farmers must engage with the practice and retain the knowledge and know-how. Similarly, this repetitive implementation exposes the practice to new users and potential carriers in the form of new fish farmers who have joined the business. In daily practice such as feeding, the skill and know-how may be easily shared between co-workers. Such daily tasks are widely repeatable, therefore, easily absorbed by the new carrier as they build competence through repeated action. However, this ease of facilitation extends to social practice that may prove unwanted or bad concerning biosecurity. For less frequently carried out practices, the annual vaccinating of new stock is a practice that has a precarious existence due to a lack of individuals capable of carrying the practice forward. The practice is reliant on the carriers in that geographical location to retain the competence in the practice. The loss of these individual carriers through employment termination, career changes and retirement can remove the competence entirely from the geographical location. This may affect the balance and synergy that has allowed this practice to be carried to this point in time. This is manifested in fish farming through the hiring of contractors to carry out vaccine protocols when the practice has been lost by fish farmers in that area.

2.5 Linking Social Practice Theory and Biosecurity in Aquaculture

Throughout this chapter, the key theoretical perspective underpinning this research, practice theory and biosecurity have been examined through engagement with a variety of academic literature and visualised through the use of examples. By understanding the concept of elements and how they provide the building blocks for practices, allows the reader to critically analyse any practice from a social practice framework. By understanding their changing dynamics and how elements establish and maintain links between other elements is vital. By recognising the complexity of social practice this research is better positioned to investigate what it means to do fish farming well and carry out effective biosecurity within the industry.

In summary, social practice theory offers an alternative framework of investigation for academics and policymakers who have, until now favoured behaviour change frameworks. Although practice theory has the conceptual range to surpass that of behaviour change, the later remains a prominent feature of the policy development landscape. Shove et al., (2010) acknowledges the attractiveness of behaviour change to policymakers, the burden of responsibility at the individual level rather than at the macro. From a practical perspective, this approach has significant impacts on the direction of policy development. Behaviour change can only offer a limited perspective; it is here that practice theory must bridge the gap to grow in relevance from a policy development perspective.

Within the parameters of a study on biosecurity in aquaculture, the theoretical approach that offered the most useful tool was selected in the form of social practice theory to understand the nature of biosecurity and what it means to do fish farming well for those within the industry. With this in mind, any attempt at influencing a change in biosecurity practices must take into account the elements of material, competence and meaning and their linkages that shift the focus away from behaviour change in a mirror of efforts to shift the focus of biosecurity understandings away from closure and to a more nuanced and less geometrically rigid understanding of biosecurity.

2.6 Applying Social practice theory to aquaculture

This research will engage with biosecurity in aquaculture as a practice. For Schatzki (2002) the concept of a practice is one that embraces a set of hierarchically organised doings/sayings, tasks, and projects, and at any given duration. In its essence, biosecurity places significant merit on the same hierarchical and organised tasks and activities. The meanings and motivations behind implementing biosecurity protocols are far more complex than merely conforming with regulations. The application of practice theory to this research facilitates the nuanced contributing factors to what it means to do fish farming well and implement good biosecurity practices across an industry. Aquaculture requires synchronisation of different practices to facilitate the productivity of the aquaculture site.

Using biosecurity as a primary objective requires a combination of practices to work in unison. For example, drafting and implementing a biosecurity plan highlights the synchronisation of several day to day, irregular and annual practices. By stipulating the need for decontamination stations before entering a site, a series of behaviours are acted upon in a predetermined sequence. The materiality of the disinfectant itself and the container is now placed in the landscape, and the installation now spawns the need to replenish the disinfectant around a predetermined timeline that best utilises the liquids ability to disinfect the footwear or tools which will be subjected to systematic dipping and washing daily. As previously examined, it is the continued implementation of a practice that allows for its longevity via reinforcement and repetition. It is those who are inadvertently tasked with carrying the practice who emerge as critically important to the success of fish health practices. Carrying this example forward, the responsible fish farmer will educate co-workers and visitors through repetitive actions as they place value in this method of infection control. Where skilled individuals are involved, the practice may exist and be facilitated in that location. The practice exists in a state of flux due to the opportunity to recruit new carriers and loss of competence through individuals leaving the sector or the area. New carriers may alter and change the practice in line with their level of competence, their desire to continue such practice or the advancement of new material items.

Additionally, competing practices may exist when an external factor threats the continuation of an established practice. For example, an external factor in the form of time constraints or inadequate staffing levels may reduce the farmer’s ability to carry out the established sequential practices relating to biosecurity on the farm. The stronger the inter practice bonds, the less at risk biosecurity as a practice is. The fluctuating nature of the trout industry in England and Wales provides an exciting template to apply social practice theory. Lien and Law (2011:70) link practice to the Atlantic salmon industry in Norway. They acknowledge the subtle differences within the industry and what it means to be a salmon farmer, 'If there are lots of practices, then it is likely that how salmon are done will vary from location to location, even if these versions of salmon also overlap'.

If the focus was to shift away from the farm level production and examine the dietary habits of potential consumers of trout, social practice theory would be ideal for further knowledge of demand and consumption of trout produce in England and Wales. Until relatively recently, trout was a popular fish choice within British homes. The emergence of the salmon industry in Scotland has usurped the trout industry's market share and has provided customers with large, filleted portions of fish. This new filleted option has proved very popular with consumers, thus removing the *competence* requirement of filleting the smaller trout portions. Consumers have shifted in practice to select the more convenient option of salmon over trout. This shift has dramatically changed the trout industry and has seen a period of stagnation and decline as filleting skills have slipped through a generational divide.

3. Methodology and methods

This chapter introduces the methodological approaches used to meet the research aim of developing a new understanding of the underlying drivers of the management and mitigation practices related to biosecurity and fish health in the freshwater finfish industry of England and Wales. To accomplish this aim the selection and application of a research methodology must be suitable to unlock such complex questions of; farmer attitudes to biosecurity, regulatory alignment and engagement on the issue and experiences shared by fish farms across the industry as they face the daily challenges of doing biosecurity well. It is notably important to add value to the understanding of how biosecurity is conceptualised and practised at farm level across the trout production sector of English and Welsh aquaculture. Expanding the current academic knowledge in this area required this research to consider the previous explorations into disease and biosecurity in aquaculture as a starting point and critically consider what lesser-explored avenues of knowledge exist and what they can offer if developed. This chapter will 1) reflect on the current research trends in aquaculture; 2) introduce and provide an argument favouring the appropriateness of the research design and methods chosen for this research project; 3) discuss alternative methodology and methods that warranted consideration.

3.1 Current Trends in Fishy Research

To date, research trends in UK-based aquaculture have focussed primarily on salmon and shellfish production. Within the salmon sector, research can be divided into several themes: Fish feed and digestion (Siwicki et al., 1994), disease (Maddocks et al., 2015) economic, social and environmental impacts (Lien 2005, 2007; Lien, 2015, Gross, 1998; Stead and Laird, 2002). Within the context of this research in the trout industry in England and Wales, the focus to date has predominantly been restricted to disease and epidemiological research on emergent and economically significant trout diseases such as Puffy Skin Disease (PSD) Cano et al., (2016) and Gyrodactylus salaris (Peeler et al., 2004 and Hansen et al., 2003).

Historically, there has been little emphasis on social science research contributions or issues around biosecurity approaches beyond traditional epidemiological or biological science approaches to research in trout disease. This emphasis is visible in the current trend in the academic literature (as explored in chapter 4) that undoubtedly focuses on the identification of key disease issues and how exposure to such threats can be minimised. In these cases, the threat is presented in the form of economically significant emergent diseases or non-native trade limiting diseases. Work to date has been successful in influencing disease understanding and approaches to biosecurity within the industry. Furthermore, such epidemiological research approaches have made significant contributions to biosecurity within the aquaculture industry, as demonstrated by the successful identification of common disease pathways (Oidtmann et al., 2011). The application of a risk-based approach (Oidtmann et al., 2013) to biosecurity in aquaculture has worked successfully in conjunction with research on the emergence of economically significant trout disease (Peeler et al., 2004; Peeler et al., 2014). The FHI has utilised this knowledge to form the foundation of biosecurity and disease management policy within the sector. This approach is manifested in the development of farm biosecurity plans which track production, antibiotic and movement records on the farm. Records of this type can contribute to advancements in disease management and risk profiling of potentially problematic sites worthy of further surveillance.

Another aspect of the FHI is the annual monitoring visits that are carried out on each aquaculture site. These field inspection visits form a significant part of the FHI tasking as field inspectors preplan their scheduled visits months in advance. These visits allow the face to face contact between farmers and the inspectorate in addition to an audit style procedure of documenting live fish movement and medication usage. Additional visits may be warranted to sites identified through the risk-based model in operation (Oidtmann et al., 2013).

The question now turns to what remains to be investigated and understood within trout based disease mitigation and management. This thesis has identified a knowledge gap in the understanding of biosecurity in freshwater aquaculture from the perspective of the stakeholders and actors directly involved in trout farming's daily tasks. For this to be developed, a detailed understanding of the practices and processes in operation at the farm level is essential. Forms of epidemiological research such as modelling are ill-suited to such approaches as they struggle to capture the nuanced approaches to more complex issues of practice (Shove et al., 2012); governmentality (Foucault, 1991), biological emergence and indeterminacy of life (Hinchliffe, 2001; Clark, 2002; Cooper, 2006; Dillon and Lobo-Guerrero, 2009) that are present in agricultural and aquacultural settings. In these instances, social science methods, especially those employing in-depth and qualitative research, can prove an effective method of unearthing important information and perspectives on biosecurity practices in trout aquaculture. This form of embedded work calls for qualitative methods outside of normal practice in the sector, and so presents a new lens from which to view biosecurity in trout aquaculture.

3.2 Setting study parameters

This project was created to investigate the biosecurity and fish health landscape of freshwater fish in England and Wales, the operating area of Cefas and the FHI.

Restricting this research's geographical scope to freshwater aquaculture in England and Wales effectively removes salmon farming from the research and the dominant Scottish production sector.

Table 3.1 Finfish Production Data (2012)[2]

	Number of sites	Tonnage of production	Finfish Value (£)
England and Wales	342	9162	£24,366,936
Northern Ireland	42	946	>£4,118,998
Scotland	415	168,006	>£550,000,000

What remains in England and Wales is a freshwater finfish sector with a distinct focus on coarse fish production and trout production. These production styles vary in the degree of intensification and the species of fish produced. Coarse fish production, chiefly carp farming, is predominately low intensive farming. Carp farming and carp fisheries are prone to the outbreak of notifiable carp specific diseases during the summer months. Summer increases in water temperatures tend to produce the conditions for diseases such as Koi Herpesvirus (KHV). Infected carp in water temperatures above 16 degrees celsius present clinical symptoms such as necrotic patches on the gills, rough abrasions and mucous and sunken eyes (Pokorova et al., 2005). The virus affects both Koi and common carp and can cause mass mortality in infected populations. However, the merits of including the carp sector in this work were discussed. The decision to primarily

[2] Production data supplied by Cefas (2015)

focus on the trout sector was taken due to the economic importance and link to retail multiples and the importance placed on fish health from consumers, the emergence of Puffy Skin Disease (Peeler et al., 2002) and the status of non-native or notifiable fish diseases within England and Wales. In comparison, the carp sector encapsulates a niche sector of aquaculture concerned with the angling hobbyist industry.

The trout industry operates distinct production pathways in the restocking, table production, and hatchery subdivisions within the industry where coarse fish production centres on carp farming for the recreational angling market. These dynamic production styles and industrial and economic factors offer greater insight into biosecurity practices that operate in aquaculture, making the trout industry a suitable sector for this research to focus on.

3.3 The Selection and implementation of Methods

To develop a new understanding of biosecurity and disease management in aquaculture this research utilised the following methods of enquiry: 1) postal and online survey, 2) a rapid-evidence review of available literature on biosecurity in the trout industry; 3) Semi-structured interviews; 4) Participant observation of field inspections; 5) Ethnographic participatory research; 6) Q-Methodology.

Table 3.2 Research Methods

Method	Aim	Participant numbers	Timeline
Postal Survey	Exploratory data to determine disease trends and fish farmer attitudes towards biosecurity	N=153 Placed in field N=48 Respondents	Jan 2017
Rapid Evidence Review	To uncover the current landscape of academic knowledge on disease and biosecurity within the trout industry.		Nov 2018
Semi-Structured Interviews	Explore issues related to biosecurity and disease management with actors in the industry	N=26 FHI (11) Fish farmers (12) Industry stakeholders (3)	2016 - 2018
Participant Observation	Explore the role of annual monitoring visits and the role of the FHI	N=4 FHI annual monitoring visits	Winter 2018
Embedded Participatory	Develop a rich account for the daily practices that are carried out on fish farms	N=6 Hatcheries (2) Table producers (2) Restockers (2)	Summer 2017
Q-Methodology	To examine potential subjectivity relating to biosecurity and disease management	N=20	Dec 2017- March 2018

The following sections will explore the selection of these approaches and their implementation throughout the research project.

3.3.1 Exploratory Postal and Online Survey

As initial desk-based research suggested a gap existed in the academic knowledge of the trout industry of England and Wales there was a need and an opportunity to develop and implement an exploratory survey that would provide valuable industry background and contribute to the generation of new academic knowledge on management practices and biosecurity concerns of fish farmers. The widespread use of surveys has established the method as an essential tool within geographical research. With its formative uses by Rushton (1969): environmental perceptions, surveys have been proven to be useful for eliciting respondents attitudes and opinions about social, political and environmental issues such as neighbourhood quality of life, or environmental problems and risks (McLafferty, 2003).

The survey development included consultation with many stakeholders, including the Fish Health Inspectorate and current fish farmers on question content issues and clarity of phrasing related to the survey questions. After the document was completed, it was piloted by fish farmers active in the trout production sector of England and Wales. The survey design followed a logical and easy to follow structure. The question order was developed and adapted through piloting. Real data – categorical and direct, farming practices related to biosecurity and disease – multiple response/frequency and Likert scale, open-ended questions on the industry in the form of free text questions (Bryman, 2004) were all utilised to uncover the available knowledge of the trout sector.

Logistically, the industry is relatively small in size (circa 150 farms). The industry has experienced zero growth in new farms in the past decade and a number of operations consolidating production to a primary site. This is in stark contrast compared to the agriculture industry that accounts for circa 35 thousand commercial holdings (Defra, 2019). While this limits the sample size, the relative size allows for the potential to sample the entire industry. The industry is familiar with requests for research projects. Such projects have until now been limited to economic, feed development and epidemiological questions. It was anticipated that a request to participate in this research would not be treated as unusual or out of the ordinary by fish farmers. Previous data collection has been carried out via the annual monitoring visits of the FHI with onsite feed trails, offering an exception to this data collection standard. The FHI annual visits to fish farms allow for the collection of data in a face-to-face setting. With this in mind, potential participants have prior experience complying with research requests when presented in person. What was unknown was the likelihood of participants responding to a postal survey. The implementation strategy was considered in advance of placing the survey in the field. The option of face-to-face data collection was favoured but effectively ruled out due to the logistical considerations of visiting 150 fish farms. Additionally, the option of utilising the research links with the FHI and allow the field inspectors to facilitate the survey was rejected, as the survey contained questions relating directly to the relationship of participants with the FHI. It was anticipated that the use of the FHI to administer the survey could exert a latent pressure on participants, resulting in response bias (Etter et al., 1997).

'Q.19 How would you describe your relationship with the Fish Health Inspectorate?'

The survey format explored three areas of enquiry: 1) Production and Site Information; 2) Disease Outbreaks and Biosecurity Concerns; 3) Management Practices. In total, 23 closed and open-ended questions were selected for this survey. Peterson (2000) argues that one should view the two question types as complements rather than substitutes for each other. The survey can be viewed in appendix 1.

The original sample size of 153 was informed by the publically available list of fish farms in operation in England and Wales, as documented by the Fish Health Inspectorate. The accuracy of this sample depended upon the accuracy of the records of the FHI not only in what fish farms are currently in operation but their postal address information. The exploratory postal and online survey was distributed to all known trout fish farms located in England and Wales in January 2017.

Following the initial deployment of the survey via Royal Mail, a total of 22 participants responded with completed surveys. Of these respondents, 21 chose to respond using the physical survey and stamped addressed return envelop enclosed within the survey pack. At the same time, one respondent chose to complete the survey using the online option via the Survey Monkey link and a unique farm identifier code provided within the survey pack. The low response rate proved problematic, and upon reevaluation after one month of the survey being placed in the field, efforts were required to bolster the response rate with appropriate follow-up procedures (Fowler, 2014).

Without such face-to-face opportunities, increasing the response rate of a postal survey was problematic. A balance was struck between efforts to convince the targeted sample to respond while considering that ‘striking the right balance between persistence and responsiveness to reluctant respondents is not easy’ (Fowler, 2014:50). The following actions were undertaken between February 2017 – April 2017 to improve the response rate: 1) Postal reminder leaflets, the leaflets explained the project information along with supplying the survey URL and unique farm reference number to allow respondents to utilise the online collection facility in instances where the survey hardcopy had been lost; 2) cold calls, were conducted in instances where contact telephone numbers could be identified. The process of cold calling allowed for a personal explanation of the nature of the project, offer the option of completion via telephone call and alleviate any concerns raised by the potential respondent. In addition, the interpersonal action of introducing oneself to the potential participant was in many cases, enough to allow for an explanation of the research and provided a challenge for the individuals to reject the request after speaking to the researcher. This personal approach has been shown to be an effective strategy compared to postal letters (Fowler, 2014:51). In total, the final figure of 41 respondents was generated through the various phases of survey responses.

3.3.2 Rapid-evidence review

To understand where this research fits, in the current knowledge of biosecurity and disease management practices in trout farming exists, it is critical to understand the current academic literature. To achieve this, a rapid evidence review was carried out on the currently available scientific research relating to biosecurity in freshwater finfish aquaculture. This strategy has proved valuable in other aquaculture systems (Garza et al., 2019). The search string utilised the Boolean operators 'OR' ,'AND' and 'NOT'. The key search terms used in conjunction with the Boolean operators are listed in Table 3.3.

Table 3.3 Boolean Operators and Search Terms

Boolean Operator	AND	OR	NOT
Search Terms	Aquaculture	Biosecurity	Shellfish
	Trout	Infection	Shrimp
	-	Outbreak	Carp
	-	Disease	Salmon

The selected search terms were strategically chosen to identify all relevant literature on trout aquaculture disease effectively. The addition of excluded search terms through the Boolean operator 'NOT' tailored this search away from the distinctly different shellfish and carp aquaculture areas. In addition to the listed search terms for inclusion and exclusion, restrictions were applied with regard to publication language and timespan. The review included only results which were published in English and included publications from 2000 – 2018 inclusively.

By utilising this search criterion via the Web of Science online database, the search generated 598 documents for initial screening. The second screening stage was designed to highlight the initial inclusion and exclusion criteria through the manual screening of article titles and abstracts. This screening stage was applied to identify articles relating to disease, welfare and fish health directly linked to the trout sector within the finfish aquaculture. Additionally, engaging with article abstracts provided clarity to the search results, and irrelevant publications were dismissed. Salt and freshwater finfish species outside the parameters of this project were excluded during the second screening stage. In the case of saltwater finfish, the decision was made after considering the distinct differences between site construction between open water ponds located in coastal areas and lochs concerning the ability to safeguard stock from disease through farm practices compared to the artificially constructed nature of freshwater fish farms.

Additionally, the species-specific diseases concerns do not overlap; the case of Atlantic sea lice (Marty et al., 2010) as the most problematic condition on salmon farms does not impact the freshwater industry. In the case of farmed freshwater finfish species, most notably carp, the approaches to farming the species is significantly smaller in scale, removed from the considerations of the food production industries as stock is produced to support the angling hobbyist industry. A full list of the screening criteria is listed below (Table 3.4).

Table 3.4 Stage 2 Screening

Inclusion criteria	Exclusion criteria
Rainbow (trout), Oncorhynchus mykiss, Brown (trout), salmonids	Tilapia, sea bass, seabream, yellow perch, zebrafish, Atlantic cod
Fish health, vaccination	-
Specific trout diseases: VHS, Puffy Skin, RTFS, Bacterial gill disease, etc	-

A third and final manual screening was carried out to identify publications that engaged with biosecurity practices as opposed to the clinical diagnosis of pathogen development in salmonid diseases. These publications were examined in further detail and presented in Chapter 2 (2.3).

3.3.3 Using Ethnographic Methodologies for Practice-Based Research

Embedded participatory research was carried out on freshwater fish farms in the south of England. This research style offers great value to understanding the practices and processes of biosecurity on fish farms. Cook (2005:167) argues for the use of embedded participatory research to help "understand the world-views and ways of life of actual people from the 'inside', in the context of their everyday, lived experiences". Ethnographic enquiry of this nature can uncover previously unknown perspectives into daily operations and practices within aquaculture. Indeed, the approach has been successfully implemented by Lien and Law (2011); Lien (2015) in the Norwegian salmon industry.

This research design has been heavily influenced by social practice theory. Through Shove et al's., (2012) understanding of practices, this research has successfully identified and engaged with key 'moments' within the disease management and husbandry practices on fish farms. These 'moments' (Chapter 5) vary from daily feeding tasks to more structured and less frequent vaccination attempts. Without the application of a practice theory approach, these human-fish interactions may have been overlooked. Instead, this research can explore the task of feeding framed in the elemental approach of material, motivation, and competence developed by Shove et al., (2012). In this way, what the farming tasks mean to those undertaking them can be examined alongside their importance in maintaining biosecurity standards. It is through these moments that the concept of care practices emerge within this research. Practice theory mediates this transition between developing rich ethnographic data while uncovering the underlying and emergent concept of care practices within aquaculture.

The fish farms chosen ranged across a variety of sizes and production styles (two hatcheries, two table production sites and two restocking sites). Experiences gained by living and working on fish farms are impossible to reproduce in methods other than those of prolonged ethnographic style. Crang and Cook (2007:39) 'acknowledge contrary to its traditional image… participant observation research is not always a matter of spending a year or two living in an isolated community in some remote part of the world. It may be 'normal' to be doing participant observation on some days of the week and 'ordinary' work on another'. The ability to document the relationships of care and domestication as they merge to form an inter-species partnership of aquaculture (Lien, 2015; Law and Lien, 2012) places this research in a unique position to develop new understandings of what it means to do fish farming well while engaging with biosecurity practices.

The selection of suitable sites began with the identification of fish farms who indicated through the exploratory postal survey (3.3.1) a willingness to participate in further research. From these respondents, care was taken to select sites that represent important nodes within the interconnected trout industry. The factors for consideration included: (1) site size, larger sites or sites with a high biological load due to a high stocking density can encounter disease management issues; (2) variety of production style, to understand the heterogeneity of the trout industry, embedded participatory research was carried out on the three different production systems in operation (table, hatchery and on-grower); (3) connectivity, sites with physical connections via waterways or transport networks for live fish movement; (4) workforce size, as an indicator of demand on the farmers; (5) Water source variation. This approach identified suitable participants that represented the heterogeneity of the industry.

Buller poses that ‘a farm is a more-than-animal place, a more-than-human place, a place of constantly shifting multi-species interactions, practices, relations and adaptations’ (2013:167). To grasp the complexity of multi-species interactions, an ethnographic approach, similar in design to the work of Law and Lien (2012) and Lien (2015) was selected. Law and Lien (2012) developed an in-depth exploration of the Norwegian salmon industry through ethnographic research methods. This research utilises ethnographic fieldwork experiences to identify and develop findings from notable interactions between the researcher, the fish and the fish farmers that reflect the challenges and opportunities for care within trout aquaculture.

To fully present the variety and complexity of the fish farm production approaches, it was critical to include a broad spectrum of fish farming experiences while incorporating a variety of production styles, including table producers, hatcheries, and restocking fish farms. The identification and selection of suitable fieldwork locations were carried out by first identifying fish farms that were open to the prospect of participating in this research. The exploratory postal survey (Chapter 4) included an option for participants willing to further participate in this research to select and complete. The respondents identified through this process were categorised by their farm production style, farm size and location. Thus, suitable fish farms were identified as the sites for embedded fieldwork consisting of prolonged periods working on the selected farms. The embedded fieldwork utilised in this research reflects the perspectives of ‘being there sufficient to experience the mundane and sacred, brash and nuanced aspects of socio-cultural life and, through observations, encounters and conversations, to come to an understanding of it' (Lewis and Russell, 2011:400). Experiencing the industry alongside fish farmers places this research at the forefront of understanding biosecurity practices within the trout sector of English and Welsh aquaculture. It required the researcher to fully engage with and develop a selection of skills and practices necessary for fish farming and vital to the industry. These interactions and practice-based experiences form the foundation of the fieldwork extracts included in this chapter.

The chosen farmers' selection criteria included their presence within the industry, production size, varying styles of production (restocking, hatchery or table producers) and accessibility.

Table 3.5 Ethnographic Site Characteristics

Site name	Production type	FTE Staff	Site Characteristics	Water Source
'Islandbridge'	Table	5	Earth ponds, sprawling site, low flow rate, transport vehicles	River
'Grey wethers'	Table	5	Earth ponds, concrete raceways	River
'Sunnyvale'	Hatchery	2	Enclosed building, Concrete raceways	Spring & borehole
'Valley's end'	Dual-use site: hatchery & restocker	4	Enclosed hatchery, earth ponds, transport vehicles	River & spring

3.3.4 Participant Observation

Furthering the ethnographic enquiry this research undertook targeted acts of participant observation to develop an understanding of the relationship between the agents of the state, the regulators and those fish farmers undergoing regulation and inspection. Shadowing of FHI visits is not a new concept as on similar approaches carried out by Bingham and Lavau (2012) during their research on regulation within food safety. During the act of inspection, the researcher shadowed members of the FHI. In total, the researcher was present on four site inspections. The inspections are the main point of contact between the state and the fish farmers. This intersection between industry and state offered a glimpse at the first-hand relationship between the FHI and the farms. Care was taken to acknowledge that "traditionally, the assumption with participant observation research has tended to be that researcher befriends and establishes sympathy and rapport with people in her/his research community". However, Crang and Cook (2007:47) argue that these are "nearly always friendships with a purpose". Although days and hours were spent in the company of both fish farmers and inspectors, there was a degree of detachment and focus maintained as these interpersonal relationships developed. Shadowing of different inspectors allowed for the similarities and unique approaches to inspection to come to the fore. As too, did the relationships and interactions between those fish farmers under inspection. These practices of inspection and interpersonal exchanges between the agents of the state and the fish farmers offer potential insight into attitudes to disease prevention and biosecurity in the trout industry.

Participant observation as a research method is not without its flaws. The covert or overt approaches flirt with the boundaries of ethics. Behar (1996) reflects on the strange nature of observation of one group of humans by another human whose goal is to document such observations. Participant observation can be unnatural in the relationship between the researcher and the participants. In many ways, this is true, and the process of participant observation can feel unnatural or distrustful. Ethnographic inquiry can be covert or overt. This research is overt and has generated data, primarily in the form of reflexive writings of the research experience, due to the aquaculture industry's hands-on nature and insights into practices of regulation and biosecurity from inspector and farmer. As the inspections provide a snapshot into the inspector's personalised approach to the task, there is need to acknowledge that sample variability is a factor not only between inspectors but also across the different fish farming operations (hatchery, restocker, table). Three inspectors were shadowed to account for such variability, and the inspection choice accounted for hatchery, restocker and table styles of production.

The shadowing opportunities were arranged with the individual inspectors responsible for the geographical area. This was carried out in consideration of the seasonal nature of the annual monitoring inspection schedule. The method provided an insight into the relationships between inspectors and the fish farmers, the flows and feeling of field inspections and greater insight into the operational approach to biosecurity within the trout aquaculture sector. Through travel with inspectors from site to site, insight into the industry was uncovered into the individual inspectors' pathways from fish farmers to working within the FHI. This method offered the opportunity to document the previously unaccounted for knowledge sharing interactions between inspectors and farmers that place the inspectors in a role beyond merely that of an auditor.

The recording of participant observation during inspections involved the six layers of description: locating an ethnographic setting, describing the physical space, describing the interactions of actors within that setting, describe the researchers' participation within in those interactions, reflections of the research process and finally self-reflections provoked by the field research (Cloke et al., 2004:200). However, in the case of shadowing during inspections, questions were held until after the event as to not interfere with the natural flow of the inspection or interfere with the participants' natural approaches. Notes were taken, and clarification on issues that required further explanation was carried out after the visit with the inspector and all accounts were written into a field diary within 24 hours of the event.

3.3.6 Semi-structured interviews

In addition to the ethnographic enquiries and participant observation, semi-structured interviews were used to gather data from stakeholders in the aquaculture industry. Crang and Cook (2007) advocate for interviews not to be treated as a separate method but instead, interviewing is a form of learning through conversation. The style and formal style of the interviews is dependent upon the setting and interview participant and research style. The semi-structured interview technique allows for a style of focussed questioning that does not limit the respondent but rather allows for a level of elaboration and dialogue that could aid researchers in highlighting hidden or overlooked points of interest that could prove pertinent (Valentine 2005). For this research project, a mixture of formal office-based settings along with on the farm interviews developed a variety of stylistic approaches. A challenging aspect of arranging interviews for this project was the flexibility of potential participants and the ability to meet in person. Where a face-to-face interview was deemed too difficult to facilitate, interviews were then carried out over the conference call. All interviews were recorded via Dictaphone or iPhone, and the audio files stored securely for later transcription and analysis.

Interviews (n=26) were conducted with FHI (11), fish farmers, (12) and industry stakeholders (Vets, feed company representatives and lobbying group; British Trout Association (3).

3.3.5 Q- Methodology and aquaculture

A Q methodology was utilised to further develop the investigation into the differences and similarities of opinions on biosecurity matters within stakeholders at the forefront of the trout sector. This method was pioneered by Stephenson (1935) and has roots in psychology. Q methodology utilises factor analysis and qualitative interpretation to identify and define shared participant commonality on issues effectively. Q methodology has been applied to several social science fields; psychology (Stainton Rogers, 1995; Stenner and Stainton Rogers, 1998; Stenner and Watts, 1998); geography (Previte et al., 2007; Price et al., 2017); political science (Brown, 1980) and environmental science (Webler et al., 2009). Q methodology excels in tackling issues were subjectivity is valued. The method was selected for this research to identify subjectivity in approaching the topic of disease management and biosecurity. Q methodology approaches a topic as Good (2000) argues as a gestalt procedure, so far as a formulation of a whole approach rather than a representation of individual opinions on an issue. A Q-methodology effectively compliments the experienced-based findings of ethnographic methods.

At the heart of Q-methodology is a focus is on the collective. Q-methodology excels in the development and interpretation of emergent factors. These factors emerge from participants sorting ‘stimulus items’ pertaining to a topic on what can be viewed as an inverted pyramid grid structure. The completed arrangements come together to form several factors or approaches related to the topic. These factors are at the core of the gestalt approach and subjected to factor analysis. It is also recognised that a key advantage of the methodology lies in its flexibility. This flexibility is apparent in applying a wide range of 'stimulus items' from quotes, statements, photographs, etc. This allows Q methodology to be used across various research topics in a novel and engaging manner that engages with the participants.

Although flexible, one must consider the applicability of this form of methodology to this research project. Watts and Stenner (2012) ask two questions one must consider concerning the use of Q methodology, does it really matter what the participants think about the issue in question? Can such findings related to the viewpoints of participants make a difference? Contemplating these questions in relation to this research, it is clear that the understanding of those intrinsically linked with the practice of disease management and biosecurity within the trout industry is of critical importance in the continued efforts to safeguard the industry from biosecurity threats. Increasing the knowledge related to the social practices of biosecurity can make actionable changes to the development and implementation pathways related to new knowledge and practices relating to biosecurity in a manner that will engage with and develop buy-in by those on farm level.

3.3.7 The practical implementation of Q methodology in aquaculture

Q-methodology has three phases: 1) collection of participant data (Q sorts); 2) intercorrelation and factor analysis of data; 3) interpretation of the emergent factors (Watts and Stenner, 2005) The development and implementation of the Q-methodology followed the format presented in Watts and Stenner (2012). The Watts and Stenner (2012) handbook on Q-methodology is the most detailed resource available on the implementation of a Q-methodology providing detailed instruction on the entire process. The development of the Q-methodology for this research is illustrated in table 3.6.

The initial stage of this method was the generation of over 50 potential statements (stimulus item) which would form the basis for the Q-set. Brown (1980) refers to the art involved in crafting and creating the Q-set. Time was taken to develop and craft the Q-set prior to any attempts to administrate it. The statements were developed through desk-based research, survey findings and through in-depth conversations with actors within the trout industry during the ethnographic phase of research.

Table 3.5 Summary of Q Methodology: Development and Implementation

Stage	Aim	Action	Result
Stimulus item development	Develop clear statements of value to the topic of biosecurity and disease management, that were suitable	Develop and refine stimulus statements. Initial statement number was refined, potential misinterpretations were removed.	38 statements related to biosecurity and disease management were developed, printed and laminated to ensure robustness
Trial	Practice the implementation of the method, identify issues before placing the study in the field	Trialled with members of the Exeter University PhD cohort	Misprints identified and replaced. Valuable practice in the implementation of the research method
Data Collection	Implement Q-methodology and collect data from key practitioners in the field	Face to face data collection (circa 1 hour per Q sort)	20 Q sorts were completed by members of the FHI, fish farmers, stakeholders
Data Processing	To process 20 Q-sorts for further qualitative analysis	PQMethod software was utilised to process the Q-Method	3 factors were identified for analysis
Factor Analysis	Examine the identified factors and provide analysis of the data	Each factor was explored to identify positive and negative drivers. Factor similarities and differences identified	Each factor is presented

Regarding the size of the Q set, Watts and Stenner (2012:60) state that traditionally a Q set comprises of between 40 and 80 statements. However, it is not uncommon for smaller Q sets as low as 25 to be viable and encourage where participant's time or attention may be fleeting. With this in mind and the design structure of the tiles and the additional statements, a 38 statement Q set will achieve the desired outcome. Each statement was carefully considered with efforts to remove inconsistencies and potential misinterpretations in the wording and the method, and Q set statements were trialled as to the suitability of statements and the structure of the sorting task. The statements operate in the collective, and they were constructed to incorporate as complete an understanding as possible of biosecurity and disease management on trout farms. 38 statements that reflect biosecurity in trout farming were selected. Including:

'Government assistance is reserved for exotic diseases'

'Fish farmers know how to deal with endemic diseases'

'Fish farmers are able to manage fish stress levels'

'Fish farmers regularly share information on diseases outbreaks with other fish farmers'

From these examples, the scope of the task is apparent with statements ranging from intervention practices of the state to fish husbandry and stress levels among the stock and inter farmer relationships and knowledge transfer within the industry. A complete list of the stimulus statements is presented in the appendix.

Once finalised the statements were printed on 10cm X 5cm white paper and laminated to ensure their rigidity while undergoing handling and sorting in the field. Each statement card was assigned a number displayed on the reverse of the card to allow for data collection. A template board was created; this cardboard template incorporated 38 individual placements for each statement card ranging from +5 to -5 in the form of an inverted pyramid distribution as presented below (Table 3.6).

Table 3.6 Q- Sort Grid

-5	-4	-3	-2	-1	0	1+	2+	3+	4+	5+

← Most Disagree

Most Agree →

This style of the template purposefully restricts the participants' placement options in a manner that focuses their feelings on particular statements. In total, twenty Q sorts were completed. Participants were selected from individuals active in the industry in the role of fish farmers, inspectors and stakeholders (Table 3.8). Fish farmers of varying experience across the various production styles were selected. A relatively large number of fish health inspectors were included. Although this presents the potential for a homogenous sample, it offers a valuable representation of trends that encapsulate both inspectors and fish farmers, which may lead to more successful policy interventions. Q-sorts were collected at the Cefas laboratory in Weymouth, Dorset and the farm offices, portacabins, kitchen tables of the participants and one pub dining table.

Table 3.7 Distribution of Q-methodology Participants

Fish Farmers	9
Fish Health Inspectors	10
Industry Stakeholders	1

It is this variety of participant that sets Q methodology apart, as Watts and Stenner (2012:23) argue this allows us to ‘understand the nature of the shared viewpoints which have been discovered, to a very high level of qualitative detail’. Completion time ranged from approximately 20-45 munites by participants. This included the reflective discussion with the researcher upon completion of the sorting task. The following steps show the process of completing a Q-sort. Each Individual participant was asked the question:

‘How is disease and disease management understood in trout aquaculture’?

Participants were presented with the 38 statement cards along with an instruction sheet containing eight points, clarification was offered if required and the task proceeded as follows: Participants read the individual cards and sort them into three stacks; ‘mostly agree’, ‘mostly disagree’ and ‘unsure’ (mixed feelings).

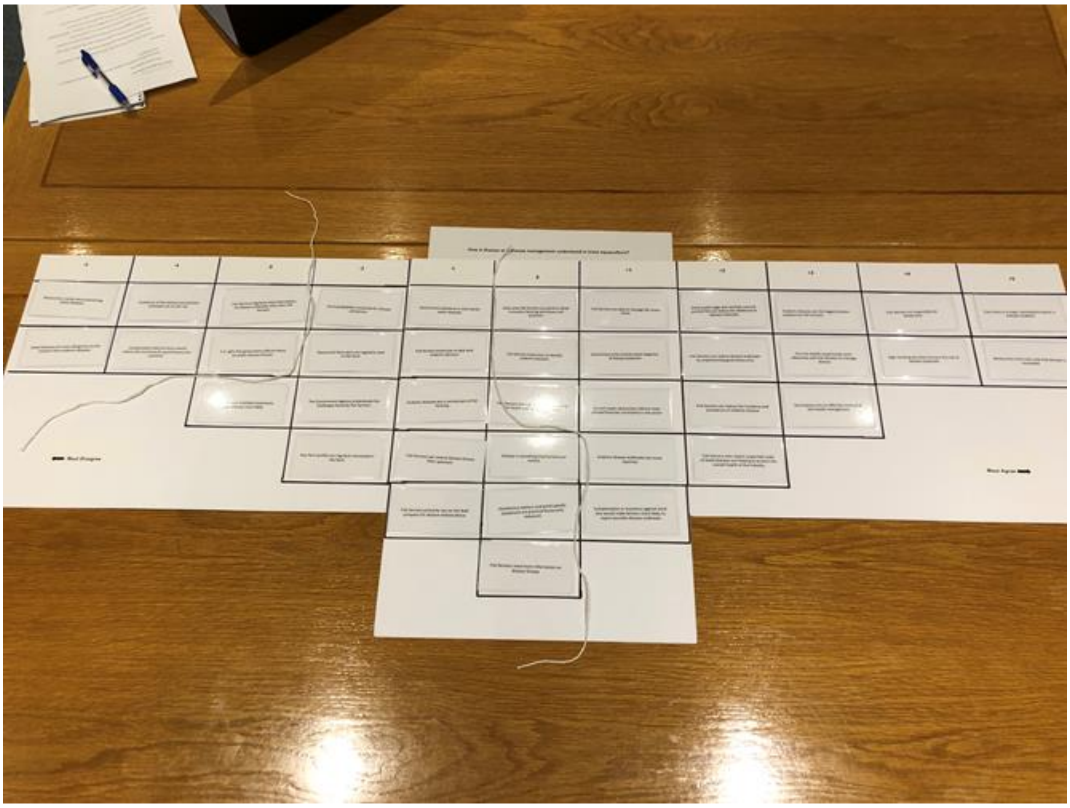

Fig 2 Completed Q-Sort (Author, 2018)

Placing the other two stacks to the side, participants were instructed to place the 'mostly agree' cards on the template spanning from +5 downwards until all the cards have been allocated places on the template as displayed in Figure 2.

This process was repeated with the remaining card stacks before the participants were asked if they were happy with the arrangement or wished to execute any changes.

3.3.8 Data & factor analysis

The completed Q-sorts (N=20) were subjected to data analysis. The two-step process involves; 1) Processing raw data using both specialised software to identify the qualifying factors; 2) Analyses of the processed factor data using a qualitative approach to present a detailed understanding of the patterns existing in the factors.

Traditional data management software such as SPSS can be used to process the data, Watts and Stenner (2012) suggest that the program's functionality to engage with factor analysis is unsatisfactory. Instead, they suggest engaging with purpose-built software packages such as PQMethod or PCQ. Both software packages have been designed to work with a Q methodology with the former being free to use. PQMethod software was selected for the initial factor analysis. After processing a 'Q methodological factor analysis can then be applied to this correlation matrix as a means of reducing it to a smaller number of factors, but now the factor analysis is looking for groups of persons who have rank-ordered the heterogenous stimulus items in a very similar fashion' (Watts and Stenner, 2012:23). Using the specialised software to analyses the data three factor arrays were identified. These arrays present gestalt sorts that can be interpreted to uncover key insight into the subjectivity of the sample. The three factors were rotated to maximise their alignment with the real participant sorts. The three-rotated factor arrays accounted for 59% of the data set's variance. The rotated factor arrays account for 17 out of 20 sorts, with three sorts being identified as confounded (where they present as significant on more than one factor). The total weighted scores for each statement relative to a factor were standardised to allow for the different number of Q sorts in the three-factor arrays. These standardised

Z-scores were then used to develop factor arrays that would represent this factors viewpoint to sort the statements. The final factor arrays were then subjected to factor analysis.

Lewis-Beck (1994:4) argues, “factor analysis is used not only as a formal method of ascertaining underlying factor structure but is also often used as a heuristic device”. It is based on the fundamental assumption that some underlying factors, which are smaller in number than the number of observed variables, are responsible for the covariation between two observed variables. (Lewis-Beck, 1994:6) Implementing a factor analysis is not a straightforward procedure. Q-Methodology’s ability to go beyond such qualitative interpretations comes to the fore as a qualitative approach to understanding the complexities and key emergent themes were applied to the data. This interpretation reveals the complexity (Stirling, 2010) of the topic and issues of importance to those participants.

3.3.9 Factor interpretation

The concluding stage requires the manual interpretation of the emergent factors. Each factor array is carefully presented to give meaning and clarity to the array's individual rankings and those that are encapsulated by it. Each factor array presents distinct trends from other arrays and provides a more nuanced understanding of a topic. In some cases, participants do not fit exclusively into one factor. In such cases the number of exclusive and shared factors are reported in the following manner: Factor 1: five fish farmers (2 exclusively, 3 shared).

Factors are presented by their *distinguishing* (both positive and negative) and *consensus* (that are shared among all three factors) statements. Within the analysis of each factor, the reference to specific statements and that statement’s distinguishing value in the factor will be presented as, e.g. (25:+4).

By examining the factors' subjectivity, this research can present (chapter 7) and distinguish patterns of practice within the trout industries relating to biosecurity and disease management. Watts and Stenner (2012) warn against an over-emphasis on cross-factor item comparisons. Instead, each factor should be the driver in its interpretation, therefore returning to Stephenson’s aim to examine the idea of holism. The presented factors offer insight into trends within the industry on biosecurity practices, and disease management more holistically.

3.3.10 Data Analysis

To analyse the quantitative and qualitative data the following steps were taken. Quantitative data, in the form of survey responses, were recorded with the survey monkey platform. Regarding the limited statistical weight of the survey data due to the low overall response rate, data analysis focused on producing descriptive statistics to overview the industry's current trends. Where possible, the analysis identified co-variance between issues of the frequency of disease outbreaks and biosecurity concerns. Ordinal data generated through Likert scale questions examined farmers' attitudes on key biosecurity and animal welfare issues. Although lacking viability as a statistical sample of the industry the survey facilitated the emergence of key themes and to be identified for future development during the ethnographic stage of research while providing a fresh insight into the issues facing the respondents.

Qualitative data analysis was applied to semi-structured interviews, participant observation and participatory research data. This data was recorded in the form of audio recordings, notes and field diary entries. Interview recordings were transcribed using the Express Scribe Transcription Software. Following the direction of Crang and Cook (2007), coding of these interviews was carried out using the NVivo software package. The transcribed interviews were thematically analysed and important insights, points and responses were coded (e.g.: disease, FHI, stress, financial, management, staff regulation, care, etc.). Broader themes were identified through this coding and key areas of interest, including the relationship between fish farmers and the FHI. These themes include disease management, regulation and care. Interview data is used throughout the empirical chapters, and interview extracts are presented sporadically to develop to ground the argument of the chapter in the words of those embedded in the industry.

Ethnographic field notes, including field diaries completed during the participant observation of field inspections and the daily notes and entries from the embedded work on fish farms were noted and coded manually while in the field to highlight in the moment reflections. These were revisited on returning from the field sites and with time to reflect on the experiences in the field. Thematic analysis was again utilised to uncover important topics encountered in the field, on the completion of the farm visits. Cruz and Higginbottom (2013) support the complementary nature of ethnographic methods and thematic analysis. Its application in this research assisted greatly in identifying and framing the larger conceptual issues of care, regulation, and biosecurity. Ethnographic experiences are framed within the theoretical contexts of practice theory and care practices. With particular reference to the moments of human-fish interactions that account for the rich ethnographic field experiences of chapter 5, the conceptual lens of practice theory (Shove et al., 2012) has been used to identify and analyse the subtle occurrences and interactions captured within these human-animal interactions. Practice theory is ideal for understanding the drivers of these tasks and why they persist in their current form or have adjusted through space and time. The introduction of practices of care (Mol, 2008) provides a suitable framework to examine the suitability of biosecurity measures on individual farms while also exploring the relationships of care in operation between members of the FHI and fish farmers (chapter 6).

3.4 Triangulation

The three-stage methodology utilised in this research project on biosecurity within the trout industry provides a sense of triangulation to the research. Triangulation draws together different 'lines of sight' on a topic to benefit the research's depth and reliability. On triangulation Berg (2001:1) argues 'every method is a different line of sight directed toward the same point, observing social reality. By combining several lines of sight, researchers obtain a better, more substantive picture of reality; a richer, more complete array of symbols and theoretical concepts; and a means of verifying many of these elements'. This is evident in the development of knowledge within this project and identifying potential locations from ethnographic research. The methodology's structured and evolving progression provides the researcher with an ever-developing knowledge of the trout aquaculture industry and the industries approach to biosecurity, as each phase of research will aid in shaping and informing the next stage. In addition, the mixed methods approach to link early quantitative data with the rich qualitative ethnographic data allows this project to present a more complete understanding of what it means to implement biosecurity and disease management practices and do fish farming well in England and Wales.

4. Biosecurity in Aquaculture

This chapter moves the exploration of biosecurity knowledge into the aquaculture sector and attempts to narrow the focus to consider the current grounded knowledge on biosecurity within finfish aquaculture. The current approaches to biosecurity in academic literature include the notable contributions of Hinchliffe et al., (2016); Donaldson and Wood, (2004); Hinchliffe, (2001); Law (2006); Braun (2008; 2013) among others. As biosecurity has emerged from the practices of cleansing, disinfecting farming spaces while simultaneously utilising surveillance strategies to control biological life movement in a manner that enables trade, while mitigating the spread of communicable diseases deemed to be of economic significance to the industry in question.

For Braun, biosecurity is 'those knowledges, techniques, practices and institutions whose concern is to secure valued forms of life from biological risks' (2013:45). The following sections utilise an exploratory postal survey on biosecurity and disease management in conjunction with a Q-Method examination of the current biosecurity approaches within aquaculture. This chapter will examine key indicators of fish farmer opinions on biosecurity protocols, disease management practices and industry threats.

Building on these farm-based perspectives, this chapter seeks to understand what it means to practice effective biosecurity from those directly and do fish farming well. To achieve this insight an approach was needed that was sympathetic to the idea that the world in which biosecurity regulations exist is not black and white, but instead, a landscape of heterogeneity made up of nuanced patterns and perspectives on how best to manage and implement biosecurity. To achieve this aim, a Q-methodology was carried out with industry actors. This methodological approach acknowledges the complicated and messy nature of the world in practice, Q-methodology can uncover subjectivity and trends in populations on a given topic. This chapter presents the results and analysis of the Q-methodology.

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4.1 The Importance of Industry and Species-Specific Biosecurity Knowledge

Similarities exist in the biosecurity challenges across a range of species from cattle, pigs and indeed fish. In all industries, stakeholders attempt to navigate international trade legislation and supply chain dynamics. Biosecurity is a constant presence in all forms of food production within the UK. Farmers are operating on all scales, face on-going challenges, threats, and potential outbreaks continuously. For biosecurity to remain effective, it must evolve in conjunction with the challenges faced by stakeholders.

Critical perspectives on the current forms of biosecurity practices 'aim to demonstrate the impracticality of closure and to highlight its paradoxical effects, but also to challenge the spatial assumptions that adhere to conventional understandings of disease, to biosecurity and, more broadly, to governing life, and so to call for a different kind of biopolitics; one that confronts the intensities that are involved as good or healthy life is reduced to mere life, and as this model is rolled out in the UK and beyond' (Hinchliffe et al., 2013:541). This perspective rejects a biosecurity approach which is just built upon 'borderlines and their implementation or varying levels of compliance for a focus on the borderlands wherein pathogens, hosts, knowledge practices and others besides intra-act to make life more or less safe' (Hinchliffe et al., 2013:540). From a policy perspective, it has been argued that social science research has a significant role to play in the formulation of disease policy, by better understanding the practices of farmers and their concept and knowledge of a specific disease can help policy development (Enticott et al., 2015). Stakeholder expertise and knowledge should be valued and is utilised within this chapter to uncover the practices of fish farmers and their attitudes and concerns towards biosecurity and disease within their industry. Relevant stakeholder knowledge should be incorporated into the decision-making process to provide the two-fold benefits of developing informed policy and cultivating stakeholder buy-in through inclusion in policy development. It is anticipated that this research will better inform policy development and engagement within fish farmers on the issues of most pressing concern.

The rapid-evidence review of biosecurity related freshwater finfish research has uncovered gaps in the current literature (2.3) relating to disease outbreaks, biosecurity concerns and management practices. With such academic sources critiqued, stakeholder attitudes were required to ground these perspectives within the industry in England and Wales.

4.2 Implementing an Exploratory Survey

Until now, there has been no active social science academic engagement beyond what has been identified (2.3) with those fish farmers tasked with safeguarding the industry. This section addresses this issue by implementing an exploratory postal and online survey distributed to all known trout fish farms located in England and Wales in January 2017. The survey consisted of 23 questions over a variety of topics aimed at producing a greater understanding of the current state of play with three areas of interest: (1) Production and farm information; (2) Disease outbreaks and biosecurity concerns and (3) Management practices. Further details on survey design, implementation and analyse is available in chapter 3 (3.3.1).

This survey attempted to gain an insight into the attitudes of fish farmers to biosecurity practices. Questions that have until this point fallen outside the focus of epidemiological and bioscience approaches to biosecurity were presented to farms in a bid to develop lay knowledge in the area of biosecurity and fish health. The following sections will explore the findings.

4.2.1 Farm characteristics

The data provided an overview of the respondent farm characteristics. Respondents primarily produce rainbow trout with significant brown trout. Rainbow trout are the preferred produce for the table production. Brown trout and to a lesser extent, coarse fish and carp are also produced on respondent sites.

Table 4.3 Type of Fish Farmed Fish

Type of Fish Produced	(Total farms N=41)
Rainbow Trout	37
Brown Trout	25
Coarse fish (unspecified)	4
Carp	3

The principal water source for farms (Table 4.4) was predominately river water or, a combination of river and spring water. This duel system is popular with sites that operate hatcheries.

Table 4.4 Water Sources

Water Sources	Number of Farms
River	19
Spring	8
River & Spring	7
Borehole	2
Borehole & Spring	2
Reservoir	2
Unspecified	1

The most delicate stock on fish farms are eggs and newly hatched fingerlings. These require a stable and high-quality water supply. Hatcheries are located inside buildings and can house hundreds of thousands of eggs and juvenile dish even in the most modest of operations. The controlled nature of the buildings alongside the spring water source help to maintain stable water temperature and protect the vulnerable juvenile fish from predation while facilitating feeding and mortality removals.

The average full-time equivalency staff was 2.5. The maximum number of FTE was 8. This small average staff size is a significant consideration in terms of the existing workload created by the essential daily tasks such as feeding and mortality removal and the site's realistic expectations to incorporate new disease management strategies.

When asked on the final market for respondents primarily produced fish for fisheries or markets. Notably, only six respondents are in the supply chain of a retail multiple.

Table 4.5 Destination of Farmed Fish

Destination of produce	Number of farms
Fisheries	28
Markets	18
Fish Farms	9
Restaurants	8
Retail Multiples	6

The sites supplying the retail multiples are highly functioning produces of the majority of trout in England and Wales. They must operate reliably to meet the expectations of the retail multiple they supply. In some cases, sites have invested in a processing facility to offer a product with a longer shelf-life, an attractive prospect for their intended customer.

4.2.2 Diseases

This section will explore data relating to fish disease. A key objective of the survey was to determine the prevalence of fish disease and farmers' attitudes to both diseases and measures of control. This survey develops an understanding of the current disease landscape through a series of three questions. Firstly, it was pertinent to understand the commonly occurring disease issues on farms and what frequency they have presented in recent years.

Q: 8: Have any of these diseases occurred on your farm in the last five years?

Participants were presented with a comprehensive list of endemic diseases. The list was compiled through an examination of the current literature on trout diseases. The second stage of question development included consultation with experienced members of the FHI on the list of known endemic diseases. An additional two diseases were added along with the more prevalently used name for the ‘white spot’ disease ‘Ich’ from this consultation. The addition of the five-year time domain (2012-2016) to the question was included to facilitate tracking of disease incidence over recent years to develop an understanding of the increasing or decreasing impact of endemic diseases on farms.

Participants reported an overall increase in endemic disease occurrence over the five years. Table 4.6 illustrates the total number of disease occurrences each year, the average number of disease occurrences per farm and the year by year fluctuation of disease occurrences.

Table 4.6 Disease Occurrence 2012-2016

	2012	2013	2014	2015	2016	5 year Avg
Total number of disease occurrences reported per annum by sample (N=41)	115	118	134	137	128	126
Average number of annual disease occurrences per farm per annum	2.80	2.87	3.26	3.34	3.12	3.07
Annual increase/decrease	-	2.6%+	13.5%+	2.2%+	6.5%-	-

The notable increase between the years 2014, 2015 and 2016 suggests that endemic disease incidence rates are fluctuating in the 41 respondents. What is uncertain is how this applies to the entire industry in England and Wales. However, this presents a finding statistically limited that endemic disease issues are a common occurrence for respondents.

Of the diseases that were accounted for, Rainbow Trout Fry Syndrome, Red Mark Syndrome, Saprolegnia, Costia and White Spot (Ich) were the most commonly occurring.

Building on this disease data, participants were presented with the same list of endemic diseases (Question 8) with the addition of all notifiable diseases applicable to England and Wales and asked:

Q.9: How concerned are you about the following fish diseases in relation to your farm's productivity?

Using a Likert scale, participants indicated their level of 'Not Concerned (1), to 'Very Concerned' (5). This question was designed to expand on farmers' perspectives of disease within the industry by exploring what diseases (endemic or notifiable) diseases proved the most concerning. Table 4.7 presents the findings of the most commonly occurring disease (Question 8) alongside the diseases that participants are most concerned about (Question 9).

Table 4.7 Survey Questions 8 & 9

Top 5	Q8:Most commonly occurring	Q9:Most concerned about*
1st	Rainbow trout fry syndrome	Red mark syndrome
2nd	Red mark syndrome	Rainbow trout fry syndrome
3rd	Saprolegnia	White spot
4th	Costia	Puffy skin disease
5th	White spot	Enteric red mouth

*concerned… in relation to your farm's productivity?

A clear overlap exists between rainbow trout fry syndrome (RTFS) and red mark syndrome (RMS) as the most commonly occurring diseases on fish farms in the last five years (2012-2016) and the diseases that fish farmers are most concerned about in relation to the productivity of their farm. To further develop this issue, the following question was asked:

Q10: Of the diseases listed in Q9, which 3 are the biggest threat to the industry?

Table 4.8 Trends in Trout Disease Sentiment

Top 5	Q8: Most commonly occurring	Q9: Most concerned about*	Q10: Biggest threat to the industry?
1st	Rainbow trout fry syndrome	Red mark syndrome	VHS
2nd	Red mark syndrome	Rainbow trout fry syndrome	Rainbow trout fry syndrome
3rd	Saprolegnia	White spot	Red mark syndrome
4th	Costia	Puffy skin disease	PKD
5th	White spot	Enteric red mouth	Furunculosis

*concerned… in relation to your farm's productivity?

This question attempted to merge both endemic and exotic diseases concerns in participants' minds to identify trends linking disease occurrence with farmer concern and the threat to the overall industry. Again, the endemic diseases of RTFS and RMS are present in all categories, from the most commonly occurring diseases, those that pose a concern to a fish farms productivity and a significant threat to the overall industry as illustrated in table 4.7. A notable inclusion in table 4.8 is VHS as the disease that is listed as the biggest threat to the industry.

4.2.3 Biosecurity

This section will examine questions related to biosecurity and disease management strategies.

The exploratory survey extended beyond investigating disease issues and the relationship between fish farmers and the FHI. The survey offered the opportunity to question farmers on their very confidence in the viability of their farms and the key issues facing the sustainability of the trout industry in England and Wales. Respondents were asked the following series of questions;

Q11: Which of the following potential upstream threats to fish health and production are relevant to your farm?

Participants were given a number of common issues plus the opportunity to highlight other threats.

Table 4.9 Upstream Biosecurity Threats

Upstream threats	Respondents
Low flow rate	31
Agricultural runoff	16
Upstream water treatment plant	11
Upstream fish farm	8
Angling	6
Upstream fishery	5
Wild fish	5
Upstream restocking	4
Other recreational activities	3
Other (silt, building runoff)	2

Of these threats, low flow rates were identified as a key issue for respondents as a potential threat to fish health and productivity. Additionally, respondents identified agricultural runoff and other forms of upstream pollution as threats to farms. Participants were asked the follow-up question;

Q12: How concerned are you about the following upstream factors as a threat to productivity and fish health on your farm? (Concerned meaning, how they might affect your farm's profitability)

This question was presented in the form of a Likert scale and participants were offered the scale of 1-5 from ‘not concerned’ to ‘very concerned’. In addition, a not applicable option was available for upstream threats that are not applicable. Respondents strongly identified the threat of agricultural and pollution runoff along with low flown rates ahead of all other options.

To categories the various threats that exist to fish farms, participants were asked the following;

Q21: What are the three biggest threats to the future of your fish farm?

This open format question drew a number of answers. These have been analysed and categorised by theme, a full list of reported threats available in appendix one. The three biggest threats identified by participants were:

1. Market forces: feed costs and sales opportunities;
2. Disease: both endemic and non-native;
3. Bureaucracy: water framework directive, audit parameter costs.

The challenges facing fish farmers are broad and wide-ranging. They can disrupt aquaculture operations in the short term and also exert significant tension on the long-time viability of operations.

4.2.4 Doing better biosecurity practice

This section will introduce the survey findings related to the management practices related to biosecurity and the future of respondent farms.

One significant area of interest that required attention was the relationship and interactions between fish farmers and the FHI, the regulatory body tasked with overseeing the trout industry's biosecurity. It was anticipated that the dynamic between a regulatory agency and the regulated might present in as a classic hegemonic top-down relationship or perhaps something else was at play within the trout sector.

The survey uncovered significant findings relating to the fish farmer feelings towards the FHI that until now have not featured in the academic debate on biosecurity in aquaculture. Survey respondents reported an exceptionally positive relationship with the regulatory body. The duel nature of the FHI as a regulatory agency and also as a source of information and knowledge on fish health fosters good working relationships in the minds of fish farmers.These findings are supported by the answers to the following questions;

Q.19 How would you describe your relationship with the Fish Health Inspectorate?

Participants were given a frequency scale ranging from 1 (“Negative”) – 5 (“Positive”) in which to answer. Participants were also asked to expand on their choice. In total, 41 respondents replied with a weighted average of 4.73. Additionally, 87% (n=36) of respondents indicated the highest possible positive score when answering this question. This initial finding firmly establishes the importance of the FHI for those respondents. Furthering this point, participants were given the opportunity to expand in greater depth on their relationships with the FHI. This opportunity to further expand on the relationship received responses such as:

Gold Star! Not often that a regulatory body works with rather than against the industry!

Fish Farm 879

This response is indicative of the general attitude to the FHI by respondents. An emergent theme that is highlighted by this survey is the approachability of the regulatory body. Participants acknowledgement of the role of the FHI outside of surveillance and enforcement.

‘Q.18: Where do you access information and advice on fish health?

Question 18 clarified the role of the FHI as 87.5% of respondents reported that the FHI along with other fish farmers, were the most frequently utilised resources for information and advice on fish health. Reporting higher than veterinarians and trade associations it is unquestionable the position of importance the FHI occupies in this duel role of surveillance and advisory capacity.

Good working relationship is vital to ensure health of our stock

Fish farm 779

We have a good working relationship with the FHIS [sic], and value their input into disease control and biosecurity

Fish farm 670

It shall be noted that definitive statements on these interactions between fish farmers and the FHI cannot truly be made from one survey, instead this area of enquiry will be returned to in later chapters in greater depth. What is open to discussion is how best to communicate essential new knowledge on disease management, fish health and biosecurity to fish farmers at farm level.

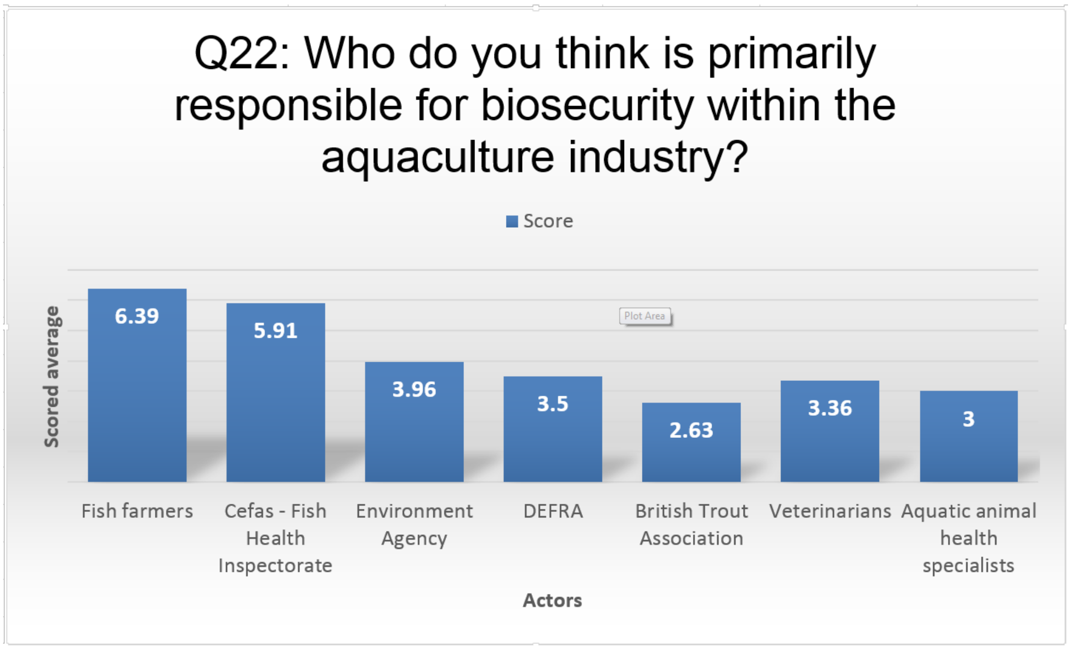
To understand how farmers conceptualise biosecurity responsibility. The following questions were asked:

Q16: Does your farm have insurance policy relating to stock losses due to disease outbreaks?

40 of 41 respondents completed this question. Overwhelmingly 33 respondents reported their farm did not have an insurance policy to cover disease losses. Of the farms without insurance coverage, 25 cited the high financial cost of such policies as being excessive and not viable.

A key question that this research seeks to answer was where responsibility for biosecurity rests within the minds of industry stakeholders. The respondents were presented with a range of actors and tasked with ranking those responsible. From 1 most responsible to 6 least responsible:

Table 4.10 Biosecurity Responsibility



Respondents place the responsibility firmly on the shoulders of fish farmers, closely followed by the Fish Health Inspectorate.

4.3 Discussion of survey results

To this point, the survey results have provided new knowledge by identifying the current approaches to biosecurity and disease-related research that is relevant to the industry. Survey results that have identified disease trends and fish farmer perspectives on individual diseases, biosecurity responsibility, sources of biosecurity information and relationships with regulatory bodies. What follows is a critique of how this data contributes to a new understanding of biosecurity within aquaculture.

4.3.1 Acknowledging the gaps in established knowledge

The utilisation of an exploratory postal survey in conjunction with current academic knowledge (2.3) provides a helpful approach to merging theory and practice. Furthermore, this direction of research has revealed an interest in fish health that extends beyond disease. By identifying and analysing these research trends this chapter has identified the key themes of 1) Disease, surveillance and vaccinations; 2) Diet and probiotic usage; 3) Alternative treatment innovations. These themes have, until now dominated the attention of academic research. They account for inputs into the aquaculture system from feeds to vaccinations. What is unaccounted for is a focus on practices and to a greater extent, the social economy of fish farming. By examining these trends in conjunction with the postal survey data, this chapter has presented a sector with contrasting focuses and a gap within the current academic knowledge on the messy and complex issues of doing good biosecurity on fish farmers.

The disparity presented in Table 4.4 between disease the most commonly occurring, most concerned about and the diseases with the biggest threat to the industry; draws considerable attention to a previously unknown dynamic within attempts to generate fish farmer buy-in and cooperation.

Furthermore, as the established literature focus is on the application of surveillance practices for non-native diseases, the novelty of an emergent disease (Puffy skin disease) and the use of vaccinations for ERM, there is a distinct lack of attention on methods and practices to impact endemic disease. The prominence of endemic disease within the industry has emerged through the postal survey as a key issue for fish farmers active in the daily task of maintaining fish health on sites across England and Wales presents a knowledge gap. Additionally, research on the issue of alternative treatment innovations is an area where fish farmers may benefit greatly from in the short to medium term as the very real challenges faced by fish farmers are of considerable value to the sustainability of the sector.

It is important that the research focus reflects the issues faced in the field. The question of which diseases are of concern to fish farmers is an engaging one. This research questions if farmers and regulators share the same sense of concern for particular diseases. It can be argued that the 'will to closure' approach to biosecurity shifts the focus of endemic diseases on to individual farmers and relegates endemic diseases to husbandry practices and aware of the state intervention. This division of disease brings into question how biosecurity is acted on by policymakers and farmers within the aquaculture industry.

4.6.2 Farm characteristic

A key consideration that has emerged from the farm characteristic data is the low level of staff working on fish farms, with an average of just 2.5 FTE members of staff working on farms. Questions emerge on respondent farms' capacity to complete the common practices that are seen as an essential part of doing fish farming. This staffing stress may drive decisions and biosecurity practices on fish farms. This is particularly relevant to the labour intensive practices of vaccination protocols.

The reliance on upstream sources of water is worth consideration. The stability of this water supply is perhaps the most precious resource for farms. It dictates their location and their ability to carry out their chosen style of production effectively. Hatcheries and dual operation sites favouring fresh spring water places them in an advantageous position by neutralising the likelihood that this water source can become contaminated.

4.6.3 Developing disease data

A number of interesting results emerge through this disease-related data relating to the nature of endemic diseases, causing concern for respondents and the interesting case of VHS as the most significant threat to the industry.

The prevalence of endemic diseases as threats to both individual farms and the wider industry is an indication of the reoccurring problem that farmers are faced with. Both RTFS and red mark syndrome are the most prominent examples. RMS is an endemic disease that thrives in what Peeler et al., (2014) describe as the 'highly integrated' rainbow trout industry. This integration refers to the movement of juvenile fish from hatcheries to other farms for further on-growing for the table or restocking market a key element of trade. Peeler et al., (ibid) argue that 'it is highly likely that the spread of RMS within the UK has been primarily through live fish movements', effectively the spread of the disease is a biosecurity concern that has been developed and facilitated through the integrated nature of the trout industry. The disease's economic impact is found at slaughter, the fish infected with the disease present clinical signs of severe degradation of the carcass, which impacts significantly on the profit margins of producers. Considering this impact on profits, it is understandable why such economically significant disease is of great concern to fish farmers individually and for the wider industry. Respondents are equating significant concern about two frequently occurring endemic diseases. This seems at face value at odds with legislative approaches to biosecurity that focus significantly on non-native and notifiable diseases which may threaten the industry. Instead, it is these frequently occurring endemic diseases that retain their place in the minds of fish farms as being considered problematic.

Surveillance of trout disease in England and Wales is the responsibility of the FHI. Embedded within the act of surveillance, there are many overarching choices made as to what diseases are deemed worthy of resources both in the sense of laboratory experiments, physical inspection, containment and control notices. It is often such logistical and economic factors that influence biosecurity objectives. Divisions of disease can often be distilled to the categories of endemic and exotic with significant value of retaining a country's disease-free status. The categorical division of this nature creates a situation where some diseases are treated as more important to the production sector than others.

The rationale for this division can extend to the severe mortality levels associated with an outbreak, the cost and burden on the state related to the ongoing surveillance and enforcement of the disease or the trade limiting nature of an exotic disease. The remaining diseases that fail to meet this criterion are clustered together to form a collection of endemic diseases. These are diseases, which have already established their presence and are often reoccurring in a given geographical area. In most cases, the endemic diseases in question do not limit trade across geographical or political borders. Endemic diseases are often associated with the industry as an unavoidable part of producing trout within aquaculture and other animal production industries.

In some cases, endemic diseases are deemed to be not economically viable for eradication. Farmers must contend with these disease incidence on a reoccurring basis. This leads to the development of site-specific strategies and practices of stock management to mitigate the presence of the disease. Treatment strategies may utilise effective vaccination protocols when available and economically affordable. Indeed, more acute stock management practices such as early exposure to conditions where second-year immunity are prioritised and popular within the industry. Currently, fish farmers must work within their given environment through husbandry skill and stock management knowledge to mitigate these endemic disease concerns. In the case of white spot disease although it is a reoccurring issue for farmers, white spot is a disease which can be effectively controlled.

White spot presents annually – usually manageable without losses

Fish farmer 299

This acknowledges that an increase in the occurrence rate may not necessarily relate to a significant increase in the level of concern or heighten husbandry and biosecurity practices on farms which may or may not change the frequency of endemic disease outbreak. If the disease can be effectively combatted without the farm experiencing significant mortality or financial loss, then it is within an experienced fish farmer's capabilities to instigate preventative measures such as a vaccination or early exposure program.

In this survey, the presence of VHS as the most significant disease threat to the industry requires further development. The disease is a severe viral condition responsible for substantial losses in farmed rainbow trout around Europe. In addition to rainbow trout, the disease has returned positive tests in a number of fish species including haddock, cod, plaice, rockling, whiting among others across northern Europe (Raja-Halli et al., 2006). The presence of VHS within Wales and England's aquaculture industry has been limited to a single case. This outbreak event may be attributed to the VHS outbreak event of 2006 that was isolated and controlled by the FHI on one farm (Stone et al., 2008). Due to the small scale of the industry and established nature of farms, this disease event is known throughout the industry and is potentially reflected here by respondents indicating VHS as their greatest perceived threat.

For the wider trout industry, the ability to stop the spread of the virus and eradicate the disease is a notable victory for the industry, and the FHI as the UK currently holds a disease-free status for VHS. This status and the EU legislation (Anon, 2006/88/EC) facilitate live fish trade while restricting trade exposure from countries with VHS present. As the most likely disease pathway is through infected live fish (Hedrick,1996), the UK is effectively safeguarded through these trade restrictions. However, the industry is still at risk of an outbreak due to the trade of eviscerated carcasses. The carcasses that are not included in the EU legislation on movement of fish are shipped to processing sites across England and Wales. VHS has the ability to survive in fish tissue for up to eight days at temperatures of 4 degrees celsius or for several months in frozen fish tissue (Menezes, 1977; Jørgensen 1970).

Fish farmers expressing concern about an outbreak event is unsurprising as the virus has the potential to cause devastating mortality (80-100%) in fry (Smail and Snow, 2011). An outbreak event of this type could close many production sites permanently. Pearce et al., (2014) provide a qualitative risk assessment on the likelihood of introduction and establishment in England and Wales. They conclude that four pathways currently exist for VHS to make its way into water networks through run-off wastewater, spread via rodents and birds; failure of the water treatment plants; direct discharge into a watercourse. Although the likelihood of entry is high, the risk of establishment through the identified pathways is very low. However, Pearce et al., (2014) acknowledge that uncertainty is present relating to estimates of the pathway potentials to a high level (EFSA, 2009). The tension that lingers around VHS combined with the recent history of the disease places it at the centre of discussion on biosecurity. Although it is not present in the day to day lives of respondents, there is undoubtedly a lingering spectre of the 2006 outbreak that appears to value the efforts of the FHI to retain the disease-free status of the UK. Alignment exists between the FHI and fish farmers perhaps more so on in the case of this notifiable disease more so than other threat faced by fish farmers who are distinctly focussed on endemic threats. This survey has indicated that alignment exists regarding one of the most severe known biosecurity issues. With such alignment, the industry can continue to work in partnership to maintain vigilance and surveillance on this notifiable disease.

4.6.4 Developing biosecurity practice

The survey respondents were tasked with completing a series of questions that aimed to document the non-disease specific threats that fish farmers encounter on their farms and those threats that may place the future of their farm in jeopardy.

Of these current threats, respondents emphasised issues that occur outside of the fish farm's boundaries, therefore out of the direct control of the fish farmers. The prominence of low flow rates, upstream pollution and agricultural runoff expose the minimal control available to fish farmers who rely on their water source. Live fish movement facilitated by humans is acknowledged as the most prominent manner of disease spread between fish farms (Oidtmann et al., 2015) these results highlight that although phytosanitary controls and movement practices can limit the spread of disease. Fish farms are never entirely free from the spectre of an unknown mortality event linked to contaminated water quality or water levels. Due to the nature of the production environment, fish farmers must maintain a relatively short-term and reactive stance towards threats when this focus is shifted to consider the future threats to respondents fish farms the trend towards economic and bureaucratic elements of the industry that exhibit tension through increasing costs, reductions of available water sources. These tensions apply pressure on the resilience of the fish farmers to adapt to threats of all types to the future of their farms.

The finding that other fish farmers and the FHI account for the key sources of knowledge and information across the industry are significant in considering how knowledge of disease and biosecurity can be disseminated effectively, as does the acknowledgement by participants of the threats faced by the industry and how they can be acted upon. This is particularly noteworthy in the presence of bureaucracy within the industry. Bureaucratic demands are placed on fish farmers from the application of a site for production down to annual auditing requirements and changes in water directives, and together these contribute to the industry 'being stretched' (Hinchliffe et al., 2017) to comply with the regulatory provisions. This is particularly the case with Environment Agency legislation and the threat of future abstraction reforms that may significantly impact farms' viability.

An interesting finding is the strength of the relationship that exists between fish farmers and the FHI. The finding can be attributed to the inspectors' past experience as fish farmers and the relatively small number of inspectors that foster good working relationships built on trust and mutual respect. The sense of partnership and trust is likely to promote and maintain good biosecurity practices across trout farms in England and Wales. Statements such as fish farmer 879's declarations of support for the efforts of the FHI are not uncommon amongst respondents. With the Inspectorate comprising of former industry officials and former fish farmers, it is reflected favourably as professional links and relationships have developed over time. Expanding on the point of 'regulatory body works with rather than against the industry', this should not be taken in isolation as the industry is engaged with several accreditations and quality assurance schemes such as Quality Trout UK, Freedom Foods, Global Gap in operation, along with the internal audit requirements of the major retail networks. For the overwhelming majority of respondents to acknowledge the relationship with the FHI as positive suggests that the regulatory body's approach is positively impacting the industry.

Although the FHI-Fish farmer relationship's primary role is that of surveillance and enforcement, this survey identified the important role the FHI occupies as a source of information on disease and biosecurity for fish farmers the level of importance placed on this relationship should not be undervalued. For fish farmers embedded in the industry, the FHI represent a source of knowledge and expertise to access. This presents the opportunity to utilise further this link between regulatory enforcement and the potential to impart useful biosecurity advice via the medium of the inspectors that mitigate the potential of a negative reaction to top-down knowledge transfer.

In light of such overtly positive responses to fish farmer attitudes to the FHI there is value in examining where these feelings stem from and their use within the industry. Although the survey sample size permits generalised analysis rather than statistical rigour, there is value in such overwhelming trends, such as the positive relationships between the regulatory agency and those under regulation. The positive relationship between the FHI and farmers may be due to several factors; 1) Inspectors have all worked within aquaculture. Therefore, professional respect exists amongst farmers for the knowledge and experience of the inspector; 2) Inspectors establish a working relationship with farmers over the course of annual visits and the relatively small scale of the industry spreads reputations; 3) Fish farmers tend to be restricted to their site with minimal opportunity to engage with peers in a professional manner related to fish health debates, this leaves the FHI to fill this knowledge void as a trusted source of information.

To understand how these relationships and attitudes to biosecurity manifest in the field, it was necessary to further explore stakeholder perspectives on the industry. This required the implementation of a Q-methodology to help illustrate these forms of industry knowledge and perspective.

4.4 Legitimising new knowledge

Enticott and Wilkinson (2013) argue that those involved in animal production industries often possess practical knowledge that is interwoven in their very identity as sheep, dairy or fish farmers. There are well-documented accounts of state officials failing to identify the complex relationships of stock persons as carer and guardian to the determent of attempts to implement technical advice (Wynne, 1992, 1996). With these past failings in mind, Enticott and Wilkinson argue that to improve biosecurity practices, it is important to remain open to different forms of knowledge and expertise while also finding ways to accommodate different perspectives on animal diseases (2013:92). Q-Methodology fits this need to identify and critique a variety of perspectives on biosecurity and disease management practices from, crucially, within the industry.

Fig 3 Cramped Q-sorting in the field. (Author, 2018)

4.5 Implementing Q and analysing factors

The development of the concourse statements grid structure that forms the basis for the method is explained in detail in Chapter 3 (3.3.7-3.3.10). In total 20 participants (10 Fish Health Inspectors, 9 fish farmers and 1 industry stakeholder advisor) were tasked with sorting the 38 statements into the inverted pyramid grid (Figure 3). During the field-work, the novel and tactile nature of the task, in combination with the freedom to change their early placements and reevaluate how they conceptualised the task, generated significant enthusiasm and engagement from the participants. All of the sorts were carried out face-to-face in a variety of locations, from meeting rooms to kitchen tables and porta-cabin offices. In each case, participants were presented with the randomly ordered statements and directed to sort them into three groups, ‘agree’, disagree’ and ‘not sure’. These groups were then sorted on the grid, with participants selecting what statements they most agreed with. It was common for participants to reorder their selections upon reflection before presenting the completed Q-sort for recording. A data and factor analysis were applied utilising the PQMethod software. This provided gestalt factor arrays that were then qualitatively analysed to provide the factor interpretations that are presented in this chapter (Watts and Stenner, 2012).

Emerging from the analysis are three detailed factor interpretations:

- Factor A: Endemic focussed; profitability not a factor in biosecurity;
- Factor B: On-farm controllables, fish stress and from off-farm threats;
- Factor C: Inward focussed, biosecurity key for fish farmers

Each factor interpretation presents a nuanced approach to understanding the elements integral to practice to endure, *meaning, competence and material* (Shove et al., 2012). This stakeholder-driven data from fish farmers and fish health inspectors and industry stakeholders offers a contextual understanding of biosecurity within the industry. This is an important factor; social practice theory approaches argue against behaviour approaches to auctioning change individuals across different, social, cultural and geographic conditions. Instead, this approach highlights the historically and culturally specific trajectories of what people do as they reflect the three elements of meaning, competence and material (Shove et al., 2012:145).

To assist in understanding each factor one needs to consider the following: 1) each factor array interpretation reflects the stimulus items ranked on either extreme of the sort (+5 and -5) and those items that ranked higher and lower in the factor in question compared to the other factor arrays.

4.5.1 Factor A: Endemic focussed; profitability not a factor in biosecurity

Explains 19% of the variance, has an eigenvalue of 3.8, and includes 3 Fish Health Inspectors, 2 fish farmers and 1 industry stakeholder.

For this shared viewpoint, fish farmers can reduce disease outbreaks by implementing good biosecurity (31:+3). However, there is less support for the idea that biosecurity farm plans are regularly used on the farm (35:-2). The viewpoint strongly disagrees with the idea that a fish farm's profitability is linked to its ability to prevent disease (3:-5), farm profits are unlikely to be reinvested in the farm (1:-3). Financial uncertainty has been created by abstraction reforms (2:+1). At the same time, compensation or insurance against stock loss would make farmers more likely to report disease outbreaks (4:+2).

There is strong disagreement within this viewpoint that biosecurity is solely about preventing exotic diseases (13:-5), this viewpoint disagrees with the government officers focus being predominately on exotic disease threats (10:-2). The viewpoint regards endemic diseases as the most significant disease problem facing fish farmers (8:+5), there is an uncertainty that fish farmers are able to identify endemic diseases and manage fish stress levels (12:-1; 28:-1). This uncertainty extends to the ability of farmers to adopt innovative techniques (33: +1).

4.5.2 Factor B: On-farm controllables, fish stress and from off-farm threats

Factor 2 Controllable problems: endemic disease issues exist, farmers can handle their site while concern exists outside the farm boundaries

Explains 23% of the variance, has an eigenvalue of 4.6, and includes two fish health inspectors and five fish farmers.

This viewpoint strongly identifies high stocking densities as increasing the risk of disease outbreaks (29: +5).

This viewpoint strongly agrees that biosecurity measures plans are regularly used on farms (35:+4). Fish farmers are seen to be capable of reducing disease outbreaks by implementing good biosecurity (31:+1). For this viewpoint, endemic diseases are less of an issue as fish farmers know how to deal with them and they are rarely reported (8:+1; 11: +2; 25: -1). However, there is uncertainty on fish farmers' ability to reduce the incidence and prevalence of endemic disease (7: 0). This viewpoint is very concerned about the inability of fish farmers to control disease threats from upstream sources (17: -5) and some concern that the reduction of available treatments makes disease more likely (22:+2).

This viewpoint strongly disagrees with government officers predominately focusing on disease threats (10: -5), this viewpoint disagrees with the suggestion that biosecurity is solely about preventing exotic diseases (13: -4)

4.5.3 Factor C: Inward focussed, biosecurity key for fish farmers

Explains 16% of the variance, has an eigenvalue of 3.2, and includes two fish health inspectors and two fish farmers.

This viewpoint identifies implementing good biosecurity as a means of reducing disease outbreaks (31: +5). The viewpoint disagrees with disinfection stations and pond specific equipment as practical biosecurity measures (30: -2) or that compensation or insurance would reduce the incentives for good biosecurity practices (5: -5). Fish farmers do not share good practice advice on fish health with other fish farmers (21: -4).

This shared viewpoint disagrees with biosecurity being solely the prevention of exotic diseases (13: -5) while acknowledging government agencies' focus on exotic disease threats is justified (10: 0; 14:0).

To assist in conceptualising these factors, they have been plotted in a conceptual space (Figure 4). This plot is included to illustrate the perceived focus on endemic versus exotic disease and fish farmers' ability to control disease issue on farms.

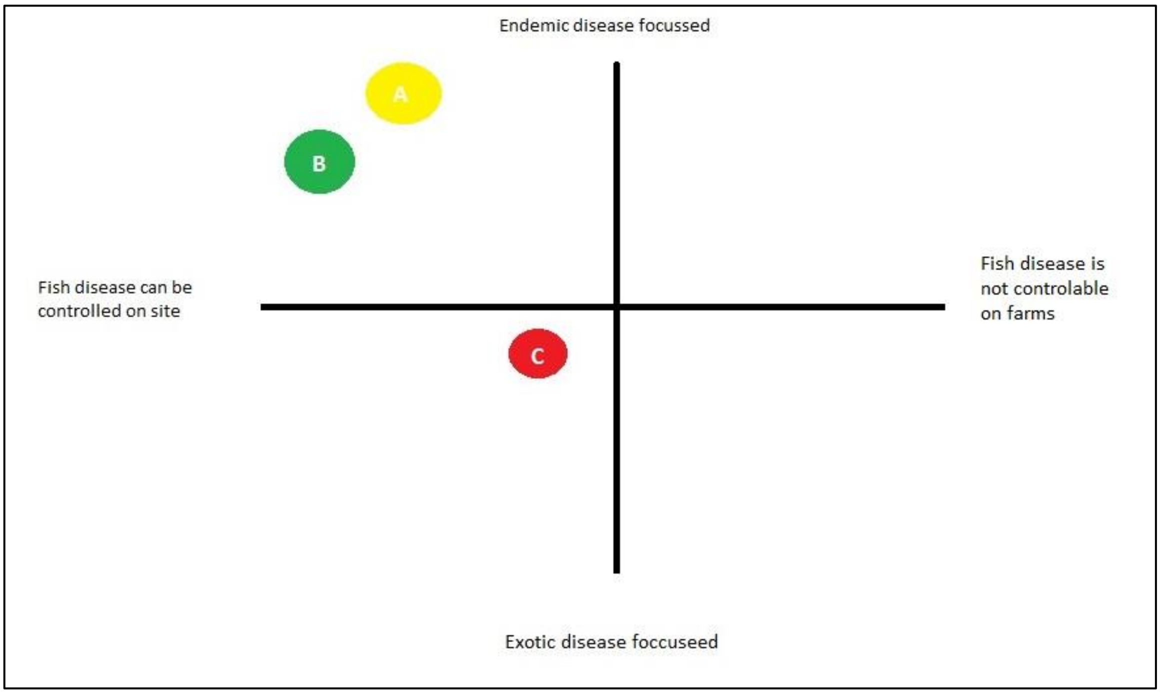


***Fig 4* Conceptual space plotting three factors according to focus on disease type and ability to control disease issues on farms**

4.5.4 Commonalities between factor arrays

It is important to note that ten statements (6, 9, 15, 18, 19, 23, 27, 32, 34, 36. All non-significant at P>.01) were non-significant for the three factor arrays. This would suggest that there exists a significant consensus across all factors on the following: there is a collective non-commitment to the idea of endemic diseases as a normal part of fish farming.

All factors strongly agree that fish stress is a major contributory factor in disease incidences and that fish farmers are responsible for biosecurity. Good biosecurity involves early diagnosis of disease presence. Vaccinations are an effective method of fish health management

A rejection that fish farmers primarily rely on feed companies for disease information, while new information is not needed by fish farmers. The FHI work effectively with fish farmers, and their assistance is not exclusively linked to exotic diseases.

The sourcing of good quality of eggs and juvenile fish is seen as a positive step in reducing the likelihood of disease.

4.6 Making Sense of the Factor Arrays on Biosecurity in Aquaculture

The three factors arrays that emerge from the Q-methodology reflect the complex nature of what it means to do biosecurity and fish health well. Each factor represents a gestalt style of insight into the collective industry. From these three factors, policymakers and regulators can develop more targeted interventions and knowledge-sharing strategies to assist the established RBS approach to biosecurity. The following sections will discuss consensus statements across factors; differences between factors; what does practice theory inform our understanding of Q-methodology.

4.6.1 Discussing Consensus statements

Across the three factors the key consensuses were towards 1) endemic disease as a normal part of fish farming; 2) government assistance not reserved for just exotic diseases; 3) the importance of early diagnosis of disease presence; 4) conflicted nature of the need for and availability of disease information; 5) the work of the FHI; 6) fish stress as a major contributory factor in disease; 7) vaccination strategies; 8) the importance of sourcing quality eggs and live fish; 9) the responsibility for biosecurity is with fish farmers.

What is apparent from the consensus statements is the common ground shared by participants across all factors on key issues that were perceived to be problematic within the industry. This finding is actionable through the design of educational strategies that utilise the collective worry about fish stress shared by fish farmers, stakeholders and FHIs as a major contributory factor of disease and other husbandry issues (Benfey and Biron, 2000; Øverli et al., 2004; Matthews and Berg, 1997).

The consensus on the importance of sourcing quality live fish or eggs links to the FHI surveillance practice of documenting all live fish and eggs' movement. For this to be present in all factors is critically important to the industry’s collective efforts in safeguarding itself from the ingress and spread of problematic disease issues (Oidtmann et al., 2011). This perspective is unsurprising as the participant sample included a number of fish health inspectors spread across all the factor arrays.

The data identifies that compensation or insurance against stock loss does not negatively impact the fish farmers and their biosecurity practices. Additionally, to further reinforce the survey data presented in Chapter 4, there was a consensus that endemic diseases are more concerning and more dangerous to the industry than any threat of exotic/listed diseases. This commonality across the roles of fish farmers and fish health inspectors on the threat of endemic diseases suggests that the regulatory body is acutely aware and in touch with the concerns of fish farmers and the industry, even if their regulatory mandate is focussed on exotic and listed trout disease.

The similarities between the three factors strongly suggest a consensus of opinion between stakeholders on key topics such as fish stress, insurance and compensation, the issue of endemic disease and critically, the responsibility for biosecurity at the hands of the fish farmers. The rationale for such a closely aligned viewpoint can be speculated. It is likely that past experiences by members of the Fish Health Inspectorate as fish farmers had a lasting impact on their approach to understanding disease and the challenges faced at farm level.

There is a lot to be considered in the closeness of the three factors. As the individual Q-sorts that comprise the factor arrays were completed predominately by fish farmers and Inspectors, a consensus on the key issues suggests that the future of the regulatory relationships is strong as the foundations exist to develop stakeholder interactions and knowledge transfer further. Garforth (2015) addresses the importance of social norms as sharing information and knowledge between farmers and other stakeholders and sources within a sector. The closeness of the factors offers opportunities to develop these subjective norms within the sector, and offer the opportunity, as Maye et al., argues to 'fully understand biosecurity behaviour, and if so required, design effective communication strategies (2017:267). As does the acknowledgement of fish farmers as the key actors responsible for biosecurity, echoing the survey findings of Chapter 4. Less well defined but nonetheless, a point of significant interest was statement 38:

'Biosecurity is the main way that disease is controlled'

Languishing in the middle/neutral rankings of 0/-1/+1 this potentially suggests a problematic use of the term biosecurity. Although all viewpoints are in consensus that on-farm practices to prevent disease outbreaks are essential and widely practised their inability to acknowledge them as biosecurity suggests that within the industry what is understood as disease management and biosecurity differs.

4.6.2 Difference in Factor Arrays

Consensus statements have been explored for their ability to identify common ground between fish farmers, fish health inspectors and industry stakeholders. Differences between factor arrays allow for the subjectivity of issues such as biosecurity to emerge.

There exist subtle differences between the viewpoints on the issue of biosecurity and how biosecurity functions in the industry. Firstly, the role of biosecurity measures plans is contested between viewpoints. Factors B and C support the regular use of the plans on farms while factor A contests this usage. This point of difference suggests that the plans could have a greater influence if the viewpoint of factor A was understood and incorporated into the plans. Factor A does not see the measures plans as a regular part of fish farming, they also are less equivocal in suggesting that biosecurity can reduce disease outbreaks. Between the three viewpoints, the use of biosecurity measures plans generated the highest levels of disagreement.

A notable disagreement between factors was the risk posed by high stocking densities. Factor B strongly supports the idea that high stocking rates increase disease incidents. While the other viewpoints were less convinced, participants offered the caveats:

'The stocking rates depends on the site, old earth ponds maybe but we've got raceways and a lot of water flowing through so it isn't a big issue for us'

(FF2)

'We keep the rate lower than a lot of farms, we can spread the fish between ponds, space isn't an issue here'

(FF8)

Across the industry sites vary considerably, the viewpoints and our interpretation suggest that high stocking densities as a default are not necessarily problematic. Instead, site capabilities should be viewed individually, the construction of the ponds, the flow-through rate, and the site's production intention provide a more nuanced understanding of a site operating within its biological and structural limits.

4.7 Summary

Presently, the UK finfish industry faces several threats in the form of various fish diseases that are pertinent to fish farms. Threats exist in many forms from the omnipresent and often predictable outbreaks of financially damaging endemic diseases to a growing concern on market forces and bureaucratic pressures that apply tension on fish farmers. Survey data has uncovered the underlying realities facing fish farmers daily, which falls outside traditional regulatory approaches to biosecurity. Fish farmers are focussed on the reality of the disease issues and water source availability that they encounter regularly while operating their farms. Prominent amongst these concerns is the issue of fish stress. A complex issue that will reoccur throughout this thesis is that fish stress demands a skilled and knowledgable response that evokes a logic of care (Mol, 2008). As Singleton argues, farmers need to be responsible for and to a variety of heterogeneous entities and involve managing their competing and varied needs (2010:50).

A knowledge gap exists between the research agenda and the socio-economic concerns of fish farmers. There is evidence in this chapter that argues for the role of the fish health inspectorate as a critical link in the knowledge transfer network that links groundbreaking research and effective biosecurity protocols direct to those fish farmers who care for fish populations across England and Wales. During the last decade, the emergence of the disease has brought this link between research – FHI – fish farmers to new prominence. Through this partnership and in conjunction with Cefas epidemiologists, Puffy Skin Disease has been identified. It is now seen as a significant economic threat to the industry – this is particularly problematic for trout fisheries where it has the potential to become one of the most serious diseases for still water fisheries to contend with (Maddocks et al., 2015). Although recovery is possible, fish are more susceptible to parasites. Currently, the lack of a pathological definition creates uncertainty for fish farmers who suspect their stock may have an outbreak of the disease. This degree of uncertainty around the disease is another stressor for fish farmers who must also contend with various other endemic conditions. In cases such as newly emergent diseases, the strength of the biosecurity network within aquaculture is tested and the importance of such a link between stakeholders is valued.

This chapter presented three factor arrays representing the shared viewpoints across a sample of fish farmers, fish health inspectors and an industry stakeholder. The consensus and disagreements between the factors have been identified. The Q-methodology data has been shown to coincide with the previous survey data on endemic disease threats and where the responsibility lies for biosecurity within the industry. The key issues this chapter raises are as follows:

Biosecurity is primarily the responsibility of fish farmers. This is the case even if there appear to be conflicting views on what constitutes biosecurity and what does not.

The three factor arrays are closely aligned. This closeness suggests that fish farmers and fish health inspectors, the majority of the participants in this Q-methodology share similar viewpoints on biosecurity and disease management practices within the industry.

Endemic disease issues, the lack of fish farmer to fish farmer knowledge transfer, disagreement on the need for more information and the use of feed company advisors suggests the industry has an issue with effective communication between stakeholders and a feeling that endemic disease issues are not considered as seriously by the state as exotic diseases.

The current approach to biosecurity is through the implementation of annual monitoring visits, focusing predominately on the auditable and traceable records of movement and medication usage in the industry. The approach has been tailored to the aquaculture industry (Oidtmann et al., 2011) and applied in a manner that accurately reflects the available resources of the FHI in the form of field inspectors and the on-farm use of the Biosecurity Measures Plan document, thus providing from a social practice lens the material and competencies required to from and carry biosecurity practices. There is the potential for more clarity in developing what farmers associate with biosecurity, creating a stronger link to their on-farm practices and the role of those off-farm surveillance and monitoring actions of the FHI.

Together the issues that have emerged through both the survey and Q-Methodology data focus on the knowledge gaps that exist within the industry, in particular, academic knowledge related to treatment options for endemic disease concerns; the consensus of perspective on what it means to do biosecurity well on individual fish farms across England and Wales. What emerges throughout this chapter is the need for a new understanding that addresses the emergent theme of care perspectives. The following chapter explores these care based perspectives within the day to day farming practices.

5. Care Practices in Aquaculture

5.1 Understanding Care Practices in Aquaculture

This chapter will examine and provide new information on the complex nature of the human and non-human interactions that form the basis for the farming of fish in the salmonid aquaculture industry of England and Wales. This chapter will argue for the importance of the relationships of care and practices of care that occur on fish farms as a critical foundation for the sector's success. This chapter will begin to develop the underlying concept of practices of care that will tie together the human-animal interactions of husbandry of this chapter. Care (Mol, 2008), and its multiplicity link this chapter and chapter 6. Chapter 6 explores care from an industry perspective on biosecurity; this chapter examines care between farmers and their fish. This conceptual shift from practice theory to care was necessary to develop this new understanding of the role care practices play in biosecurity (Higgins et al., 2018).

For Mol, 'human beings need food and shelter, and so do the animals that live with us. Someone has to harvest or slaughter; someone has to milk; someone has to cook [..]Washing is wise as well since if they are not being washed pots, pans and bodies start to smell. Failing to dress wounds may lead to infection. And as diseases and impairments also come in other forms, there tend to be sick to look after one way or another.' (2015:7). Mol strongly argues for the importance of care practices as part of daily life both for humans and within farming operations. Indeed Mol goes further by suggesting, 'if care practices are not carefully attended to, there is a risk that they will be eroded' (2015:7)

The caring relationship between the fish farmer and their stock is active in different ways and practices across the lifecycle of the fish, from artificial insemination, incubation and hatching to grow out until they are sold for restocking or are killed at market weight. This chapter will examine how care exists in aquaculture through fish farmers' everyday practices as they attempt to balance individual fish health with population health. Additionally, this chapter will explore how care practices change and adapt to new technologies and adjusted farming practices. At its core, this chapter seeks to position care practices as a pillar of importance in what it means do fish farming well.

This chapter will analyse fish farming practices that were witnessed or participated in via in-depth ethnographic to achieve this aim. Supplementary field diary extracts will focus on the distinct practice-based moments and events of fish farming such as feeding, vaccinations, mortality removal and operating within biosecurity protocols.

Firstly, the practice of feeding fish will be examined. At its core, it is the objective of encouraging the stock's growth through the template of feed conversion ratios (FCR). However, what occurs within the practice of feeding are unseen moments of surveillance and care as fish farmers interact with their stock beyond simply placing feed in ponds. This practice of care is also one undergoing adaption as automated methods of feeding become increasingly common and pose a question relating to the possible impact of such technologies on care relations.

Secondly, the use and administration of vaccinations will be evaluated in terms of their role in preventing recurring trout diseases. Vaccinations within the industry are a common practice. The most notable disease that fish farmers vaccinate against is the bacterial disease Enteric Redmouth (ERM), with the first commercial vaccine for ERM licenced in 1976 (Wangkahart et al., 2019). Trout vaccinations can occur through oral baths (Adelmann et al., 2008; Embrefts and Forlenza, 2016) in the early stages of life post-hatching to a more interventionist form of manual injection-based vaccine protocol. An example of a vaccination protocol for the bacterial disease ERM will be explored through fieldwork extracts before reflecting on this practice's unseen elements. In cases where vaccines are not available, husbandry strategies are relied on to mitigate endemic disease effects. The case of proliferative kidney disease (PKD) provides insight into husbandry approaches used by farmers to manage a disease that can be significantly detrimental to a fish farming site.

Thirdly, this chapter will consider a selection of the routine and often overlooked practices of daily husbandry (mortality removal, night-time surveillance and transportation of fish) that occur on fish farms, with particular attention given to their role in developing, carrying and implementing care on the farm. In many ways, these routine practices are highly impactful on the interspecies relationships on the farm. In these less apparent encounters, fish farmers interact in a manner that elevates or dissipates stress levels of the stock and also for the farmers. These care-practices are central to the very foundation of biosecurity and making life safe on fish farms in England and Wales.

These three areas of exploration into care do not exist in isolation. Care in these instances forms the frontline practices in the operation of effective biosecurity protocols. In understanding these entrenched fish farming practices, we can attempt to contextualise our understanding of what it means to care for fish while balancing the biosecurity responsibilities of operating a sustainable business within the statutory regulations. The following sections will introduce the inquiry method used along with its suitability for this particular research topic.

Exploring the practices of fish farming was of key importance during this stage of research. Without experiencing the collective entanglement of practices that comprise the daily lives of those tasked with the care and production of the fish, it would be difficult to understand the challenges faced at the farm level fully. With this in mind, a selection of reoccurring daily practices was identified for their importance prior to the fieldwork, including the removal of mortalities, feeding and biosecurity tasks such as equipment maintenance and disinfection, along with the common practices of grading, sorting and transportation. Additionally, after consultation with the participant farms, the fieldwork was scheduled to coincide with a number of the less frequent practices that proved great value in contextualising the interactions between fish and fish farmers. This degree of preparation yielded unprecedented access and first-hand experience with several less common or seasonally rare practices, including vaccination and, in the case of one farm, artificial fertilisation of eggs. Obtaining a skillset around vaccinations, in particular, afforded the researcher a level of expertise that proved invaluable when engaging with other fish farmers who tended to enquire about past experiences on other fish farms. They also proved valuable in contextualising the often hidden and mundane tasks that occur on the farm.

5.2 The Importance of Care in Fish Farming

This chapter aims to address one of the critical questions: how do care practices contribute to biosecurity and doing fish farming well? To answer this question requires a critical investigation of the approaches to practising care on fish farms. This chapter argues that the often unremarkable, subtle and nuanced encounters between fish farmer and fish populations are imperative to the successful implementation of biosecurity structures within the industry.

Care in Milligan and Wiles (2010) view involves a complex network of actors and actions. The network presents and maintains multidirectional flows and connections. In this sense, care is relational. There are an ongoing responsibility and commitment to a subject of care, in this case, the populations of farmed fish under the responsibility of the fish farmer (Tronto, 1993; Milligan, 2000; Wiles, 2003a; 2003b). This chapter contains detailed accounts of fish farming practices where care is present in the actions of the fish farmer and the researcher. Puig de la Bellacasa (2017:1) unravels the complexity of care in the following way arguing that care: ‘can feel good; it can also feel awful, It can do good; it can oppress. Its essential character to humans and countless living beings makes it all the most susceptible to convey control’. This chapter will examine the control attributed to the caregiver through choices that result in prosperity or death.

Finally, this chapter engages with not just life on fish farms but also death in an attempt to add to Lien's work (2015:62), who argues that a short visit to a salmon farm can be ‘overwhelming’. A fish farm may seem over industrialised, emotionless and cold - a space absent from ‘room for affective care’. Lien (ibid) is adamant that to truly experience and ‘know it differently requires ethnographic presence: presence not only in the abstract, under the guise of a scientific observer’. This is a challenging prospect as the site of a fish farm and aquatic environments as a whole present several logistical and practical challenges as being a dynamic location with agency, capable of decreased or increased water levels, oxygen content and temperature, not to mention the ability of the water body to house unseen and unwanted biological life in the form of viral, bacterial and parasitic lifeforms all the while under the management of human beings. As

Law (2016:67) describes care to not be universal and descriptive, care depends less on a formula as a repertoire that allows situated action.

The following sections contain first-hand extracts from the fieldwork diary and field notes on a number of important practices or tasks (feeding, vaccinations, mortality removal, transportation) that are at the very core of what fish farming is and how within these specific practices there is the potential to identify manifestations of care between the human and non-human.

5.3 Feeding - the task, the skill, and dwell time

The core of aquaculture is nurturing and growing fish to marketable size and weight. Achieving this objective relies on the practice of caring for and managing the lives of a dependent fish population. Central amongst these is the practice of providing a source of nutrition. Within the setting of a fish farm, the fish's natural feeding habits are disrupted and effectively replaced with a predetermined feeding plan designed to enhance the growth of the fish. By altering the agency of the fish, natural feeding habits and diets are lost to productivity, convenience and routine. The following sections explore what it means to feed fish on a fish farm, the varying ways this practice is carried out, and the added benefit to biosecurity subtly linked to this practice.

5.3.1 Fish feed: "Throwing pound coins into ponds"

Artificially created fish feed is ubiquitous in the industry. The uniformity of the product, usually small pellets available in various sizes, and the extended shelf-life and traceability of ingredients are all attractive features for fish farmers who wish to feed their stock in the most cost-effective manner. The fish feed industry is dominated by a small number of multinational companies that specialise in creating animal and fish feeds. The most prominent multinational companies operating in the aquaculture industry in England and Wales are Skretting and BioMar. Both companies cater to a differentiated consumer base of salmon and trout farmers across all production stages while maintaining the industry focus on innovation and sustainability. BioMar market themselves as a 'world leader of fish feed to fish farming industry, and supplies for more than 45 species in more than 80 countries' (BioMar, 2020). Skretting has long been the most popular of feed providers and associates their products with innovation and sustainability. Both companies stress the sustainability of their supply chain, Skretting goes so far as to introduce the 'Skretting's Sustainability programme – Nuterra' (Skretting, 2019) in an attempt to address the global challenge of applying sustainable innovation to contribute to the development of more sustainable food production to meet an ever-increasing global population. Both industry leaders are active in product development and innovation in aquaculture feed production. As pressure grows to limit raw materials from capture fisheries, innovative feed combinations and the introduction of insect meal to the commercial feed mix are in development.

For fish farmers as buyers, great value is placed on the ‘food conversion ratio’ (FCR). This measurement plays a key role in the aquaculture industry. An FCR is the amount of feed required for a fish to gain 1kg of bodyweight or ‘quantity fed/biomass gain’ (Lien and Law, 2011:72). The onus is on fish farmers to identify and implement the appropriate feeding strategies and stocking densities for their unique site to reduce the sites’ FCR as close as possible to a much sought after ratio of 1:1. In very rare cases of particularly successful operations, an FCR of less than 1:1 can be achieved. FCR is a common feature in salmonid aquaculture's stock management practices (Lien and Law, 2011). This approach to FCR, in conjunction with other inputs, has the power to designate the head office or site office into what Latour (1987) would call a centre of calculation whereby the epicentre of the farm - the farm office gains experience and knowledge through the accumulation and circulation of resources as these move on to and through the farm in the form of purchased feed, implementation of FCR and sale of finished fish. This decision-making body holds the power to make accurate strategic decisions on stocking density and feeding schedules through the knowledge and information derived from FCR and other inputs.

The following field diary extract examines the use of the feed and the FCR in practice on a small to medium-sized restocking farm.

The fish reside in different ponds, dependent on their stage of development and age. A nearby shed houses pallets of feed. Stored in large 15kg bags each pallet contains a different variety of feed which is again separated into different sizes to suit the different development of the fish. With some ponds eating over £60 worth of feed in a day – the feeding schedule and attention to detail are critically important and a hot topic for the farm manager who points out a whiteboard attached to the wall. The whiteboard displays each pond’s name along with distinct figures. The figures correspond to the feeding ration, 1 or 2 buckets, while the second figure notes the corresponding feed type and pellet size. The whiteboard shows signs of change with the pond names distinctly written in black while the corresponding feeding values have been written in a selection of different colours, indicating that this whiteboard is subject to change and review as the farm manager attempts to develop the most efficient and financially viable *feeding strategy. The feed pellets themselves, no bigger than peas, are poured into yellow plastic buckets with an accompanying small red-handled shovel. The buckets and shovels used are identical to each other, further reducing any discrepancies in feeding practices.*

In this extract, the feeding on this particular farm is highly regulated. The farm manager is responsible for determining the feeding ration required for each pond, similar to Mol's nourishing care (2010:216). Determinations of this nature have historically been undertaken by the fish farmer tasked with feeding. The fish farmer would utilise his experience to judge the pond appetite based on the time of day, weather conditions, activity levels within the pond, stocking density and previous feeding experience. However, with this reliance on the varying degrees of knowledge and experience among staff members comes a level of ambiguity as junior or lesser experienced staff members may interpret the tacit signs. With no distinct feeding strategy in place, feeding varied on any given day, creating the problem of over-feeding. This strategy of feeding by feel has become more obsolete in light of financially damaging consequences of careless farming, particularly concerning feed price increases and technological advances allowing for more accurate feeding and a lower FCR.

Mol's (2010) examination of 'nourishing care' in nursing homes encounters moments of care as personalised meals are prepared for individual residents. In the context of fish farming, collective tailored feeding programs are only suitable for populations rather than individuals. Usually, this distribution is in the form of specific ponds for fish at a particular growth phase. Expanding this point further, good care in fish farming incorporates technological advantages. Mol (2008:9) strongly favours the incorporation of technology in care, arguing against the paradigm that care is associated with 'tender love' and in this way opposed to technology. Instead, Mol favours technology that 'is not transparent and predictable but has to be handled with care'. The Skretting software AquaSim™ is an example of a technological innovation that has revolutionised the practice of feeding. The following extract from the Skretting website advertises the role of the software in aquaculture.

‘Our AquaSim tools are well established for many species of fish and shrimp and provides tools based on three criteria: biology, quality and economics. The models are easy to use and require custom inputs from the farmer, including farm dimensions, stocking plan, feed and feeding regime as well as water quality parameters.

From these inputs, a range of data can be obtained, from harvest dates to feed selection, making AquaSim an essential tool for efficient planning, forecasting and benchmarking’.

(Skretting, 2019)

The computer and app-based tool can remove a significant degree of the uncertainty relating to under or overfeeding that previously existed in the feeding operations on fish farms. The software is, however, only as accurate as the inputted data. This requires fish farmers to have up to date knowledge of the stocking densities, on the farm and in each pond or raceway. Feeding as a care practice has uncertainty removed through this network of actors, calculations and equipment. Such a spread of determinants produces more structured caring farming practices.

The introduction of a particular kind style of software has the propensity to lock-in fish farmers to a specific feed manufacturer’s product. As the feed industry is currently divided between just a handful of producers, the adoption of new technological feeding software seeks to reduce the likelihood of fish farmers utilising different producers by creating the phenomena of ‘vendor lock-in’ (Opara-Martins, et al., 2014) where consumers become dependent on a software or hardware product which is incompatible with the offerings of competitors.

Although the cost of fish feed is of primary concern to the industry, there is a value-added to the transaction between feed company and aquaculture business. A tradition of feed company representatives is embedded in the industry. These individuals answer call-outs relating to feeding strategies and disease identification. Speaking on the role of specialised fish vets in the trout sector and on safeguarding the trout industry in comparison to other animal sectors Dr Peter

Scott[3], a key figure in fish health in the UK discusses the important role of the feed companies:

> '*With fish, because you're dealing with a lot of small farms and those small farms frankly don't have the turn over to pay someone to come 100 miles, what goes on is the feed companies provide free advice as part of their service. You buy their food and their rep who has had basic training in disease so he'll come out and help. There's an extra tier that we work within the trout industry that the other industries don't have'.*

(Dr. Peter Scott – Fish Vet).

This secondary role of the feed company is further highlighted by their hosting of fish health courses, as explained by an experienced fish farmer during a face to face interview.

> *'We went on a fish health course that was run by Skretting. It was a bit of a weird one because it was very educational but it was like a sponsored program. Like [sic] if you are watching 'thinking tackle[4]' for example it's fantastic but [it's also] an hours advertisement for Korda. Use this food! As long as you understand that'.*

(Ken – Fish Farmer)

In this case, 'Ken' who is a very experienced fish farmer, is clearly alert to such courses' attempt to boost sales of fish feed through the fish health course. There is also the acknowledgement that the course serves a positive function within the industry and is another example of the feed companies' active role in supporting trout farms of all sizes. Hosting such courses on fish health by feed companies identifies a gap in the British Trout Organisation capacity or the Fish Health Inspectorate to facilitate ongoing training for fish farmers. Within this apparently simple task of feeding fish exists a decision-making network of care that is

[3] MSc.BVSc.FRCVS and RCVS Specialist in Fish Health & Production and RCVS Specialist in Zoo & Wildlife Medicine
[4] *Thinking Tackle* is a angling based television show presented by the angling equipment company Korda.

influenced not only by individual farming expertise, technological development but is intrinsically linked to market practices of vendor lock-in, producing care that is not neutral. Together these feed purchasing strategies and technological assisted feeding ratios accentuate care practices in aquaculture. Together they reduce the issue of overfeeding that can contribute to significant oxygen depletion in ponds, provide furthering education through feed-advisors and the aforementioned fish-welfare courses and boosting the ability of fish farmers to carry out this care-practice.

5.3.2 LAPs and PAPs, the case of contentious feed

The ban on the use of land animal proteins (LAPs) or processed animal proteins (PAPs) in fish feed provides an interesting examination of biosecurity drivers in fish feed production. With feed costs representing the most significant expense for farmers, LAP/PAP feeds offer a cost-effective way of reducing expenses as they are notably cheaper to process and buy than non-LAP/PAP feeds which require harvesting of source material from global fisheries. Their ban and their relationship to nourishing care are reflected in the historical role LAP occupy in the UK food production sectors. Care within aquaculture is not limited to the fish farmer – fish interactions. Instead, care extends to the farm and the retailer. LAP provides evidence of such care.

LAPs have previously been known by the common term 'meat and bone meal' (MBM), this referred to the processed remains of animal by-products used to create a financially appealing feed option for agriculture. Following the BSE epidemic of the early 1990s that struck the UK countryside, the use of intraspecies MBM gained notoriety in the public domain and prompted significant debate about the traceability of supply and operating practices of the farming and food production networks in the UK and Europe. The European Commission decision in 2001 was to ban the use of MBM/LAPs in animal feed. The ban extended to the use of such materials in fish feed. This ruling and complete ban remained in place until the European Food Safety Authority (2011) published a quantitative risk assessment review which found a negligible risk to human health from processed animal protein for food-producing non-ruminants (withholding the ban on intra-species use).

Following the publication of the 2011 risk assessment relaxation, the legislation took place in 2013 to allow for fish feed to be produced using non-ruminant processed animal proteins. With the regulatory pathway clear for the reintroduction of LAPs/PAPs feeds into aquaculture production, it encountered a significant problem. The supermarket retail chains continue to retain their ban on LAPs/PAPs: 'The use of processed animal protein (PAP) and animal-derived lipids and blood meal are not permitted.' (Waitrose, 2018:25).

In response to a specific question by the researcher, the Waitrose Health & Agricultural manager clarified as follows:

'The use of non-marine ingredients in feed diets is permitted under the Waitrose Fish Feed policies. However, the inclusion of vegetable protein ingredients must be of non-GMO origin and inclusion rates must not compromise fish welfare or the eating quality and nutritional value of the final product. The use of processed animal protein (PAP) and animal derived lipids and blood meal are not permitted.

Waitrose will continue to track developments in alternate sources of aquafeed ingredients e.g. EPA/DHA derived from algal biomass; sustainable alternate protein sources e.g those derived from farmed insects, seaweed and bacterial protein meal produced from methane fermentation. Such material may be permitted for inclusion in aquafeed diets in the future as responsible alternatives to conventional sources such as fish meal /fish oil and soy protein concentrate'.

(Waitrose Health & Agricultural Manager)

The decision to retain the restrictions on PAPs limits fish farmers' options to reduce their feed expenses where their stock is being produced for human consumption via, the large supermarket multiples. There is evidence of care through the actions of the supermarkets feed policy to protect their customers, therefore safeguarding the reputation of the company and the brand along with the product of trout, as Mol notes 'care practices are resilient as well as adaptable' (2008:45).

5.3.3 The craft of feeding by hand, automation, mechanisation and farmer-less feeding practices

To understand the differences and importance of feeding as a practice, the examples of three feeding instances are explored. Firstly, the practice of feeding on a small to medium-sized restocking farm will be explored. Secondly, the practice of feeding through automation on a highly productive table farm. Thirdly, the practice of feeding by mechanisation and reduced human interaction. How such feeding practices are carried out are examined within the context of biosecurity and disease management.

As we walk towards the pond, the fish are vibrant and active, as if to know the morning feed is imminent. I'm accompanying the farm manager Simon, as we sit our two yellow plastic buckets filled with pea-sized feed pellets at our feet we take a few moments to observe the fish. Simon seems pleased at the response of the fish to our presence on the bank. Taking a red plastic hand shovel from the bucket, Simon demonstrates the technique. A half-filled scoop, a cock of the wrist, a sharp flick similar to snapping a towel and the pellets fly through the air in an arching semi-circular pattern towards the centre of the pond. Upon connection with the water, the reaction of the fish is instantaneous as they swarm for the pellets. Another shovel full flies through the air. Simon points out the 'dominant feeders' the larger more vibrant of the community that are front and centre dominating the water. The fish thrash and splash in the newly created whitewater, eager mouths gasping for the falling feed.

"Feeding fish is similar to revving an engine, once you get them going you have to maintain the frenzy of activity by launching shovel fulls at a steady pace. Too fast and they get overwhelmed and the pellets sink, too slow and they lose interest"

(Simon – Fish farmer)

One in four or five shovels are aimed at the periphery and the reaction is again instant as the less dominant of the community who navigate the outsides of the swarm of hungry feeders. As I observe the practice I am struck by the juxtaposition between the frenzy of activity that is the boiling mass of fish loudly *splashing and lunging for the falling pellets to that of the calmness of Simon on the bank who is now set in the rhythm of the feeding, he is simultaneously scanning the pond of signs of unusual behaviour. As the final shovel fulls are thrown into the pond, the reaction of the fish has dwindled to that of mild interest.*

"It's important not to just throw pellets in aimlessly, you're basically throwing pound coins into the pond"

(Simon - Fish farmer)

The moments of surveillance enacted by Simon at the edge of the pond are used to 'identify the non-conformists' (Buller, 2013). Buller's (ibid) use of 'non-conformists suggests that there is a status quo, an ideal set of behaviours and physical attributes that the fish must exhibit to avoid the unwelcome gaze of the fish farmer. In this setting and in the trout sector of aquaculture, there is a reliance on the farmer's knowledge and eye to identify fish health problems. The industry lacks the financial capital to utilise the latest technological solutions afforded to other food production sectors (Dawkins et al., 2009) and the more prosperous salmon sector where precision fish farming techniques are emerging (Føre, et al., 2017). Currently, practices rely on the farmer's subjective experience to interpret the visual interactions before developing a perception of the current state and condition of the population of fish. It is envisaged that new applications of precision fish farming can include; 1) automated biomass monitoring, 2) automated feeding strategies and control, 3) automated monitoring of parasites levels (sea lice – salmon farms), and 4) Automated crowding control during delousing operations (sea lice, potentially other parasites).

The applicability of this technology in the trout sector is unlikely for two reasons. Firstly, the pond or raceway sizes that are common amongst trout farms are significantly smaller than the 'cities of fish' as described by Law and Lien (2012:370). Secondly, the trout industry lacks the research and development potential for the development of such technologies that may only be financially viable for a very small percentage of farms. Considering such economic realities, farmers such as Simon are left to utilise measurement and feeding efficiency practices and technologies such as the AquaSim platform to effectively incorporate new technology advancements to streamline their delivery of nourishing care.

In contrast, feeding on a larger table producer farm often incorporates technologically advanced, mechanised, timed-released and automated feeding practices. By extension, a degree of separation exists between fish farmer and their stock in such feeding strategies. The reduction of the human element is reflected in part by the lack of the embodied ‘grace’ or craft required to carry out hand feeding (Lien, 2015:60). The following two extracts that examine the juxtaposition between feeding practices across different fish farms as mechanisation and automation methods are employed.

It is mid-afternoon on the sprawling site that contains one of the largest table producing fish farms I have visited. A John Deere tractor and trailer rumble up the path before coming to a stop outside the large shed containing the pallets of fish feed. Richie, the driver of the tractor, jumps to the ground and hurries towards the small forklift. He fires the engine, and the forklift trundles across the uneven surface and disappears into the feed shed. Moments later, it reemerges; suspended above the forklift is a large canvas bag containing a tonne of feed pellets. The forklift now moving rather slowly under this load is positioned next to the trailer to suspend the feed bag directly over the trailer. With the feed suspended in place, Richie instructs me to slit the bottom of the canvas with a knife, and the feed pellets spill into the trailer with a gravelly whoosh that sends a cloud of pellet dust into the air. We repeat the loading until

Fig 5 Tractor and feeding trailer (Author, 2017)

over 3000kg of feed is in the trailer. We clamber aboard the green John Deere tractor and bounce along the path between the ponds.

Inside the tractor cab, it is a tight squeeze and obviously designed for function rather than the comfort of two grown adults. On the cab's right-hand window are two A4 pages that list the feeding schedule for the ponds. As we approach the first pond, Richie lines the trailer up and engages the Power take-off (the rotational drive shaft distributing the power from the tractor engine to the accompanying trailer). Richie then pulls a lever that enables a plastic pipe attached to the trailer to drop the angle overlooking the adjacent pond like some sort of siege weapon. He revs the engine, and a flurry of feed pellets are catapulted into the air. As they soar to the centre of the pond, they land with the intensity and consistency of hailstones. It is difficult to clearly see the interaction between fish and pellet from our position in the cab, our torsos twisted, and our heads are peering over our shoulders to monitor the stream of pellets. A few more revs, and the pellet flow is switched off, and we rumble towards the next pond. There is little time to linger between ponds, and Richie doesn't appear too concerned with observing the fish's behaviour prior to or during feeding, we have dozens of ponds to feed and the afternoon is waning.

Mechanised feeding of this type is a necessity on such a large site dominated by earth ponds. The practices of feeding fish vary from site to site. As observed in the field report, a large sprawling site of this nature requires the utilisation of machinery to complete the daily workload. A smaller site with a higher stocking density may increase the time available for the fish farmers to observe the stock. In the previous example, the dwell time between ponds is minimal to non-existent. There is a noticeable reduction in the time afforded to fish farmers to stop and observe their stock while feeding is undertaken in this manner. Any attempts to observe the fish's movements and behaviours through the prism of water and the lens of a dusty tractor window is wholly unsuitable. The site design and reduction of dwell time during feeding has the potential to allow unexpected biosecurity issues to occur or be missed by staff who are working to capacity in their attempts to complete the daily tasks within the working day. It is not to say that care is unaccounted for due to mechanisation, rather this care-practice is evolving to incorporate technological advances of material, yet fish farmers must not lose sight of the attentive nature of their relationship with their stock.

Where feeding through mechanisation retains human input, there is another option available to farms that can reduce the labour necessity through a feeding practice devolved of human interaction. Automation of feeding through timed or on-demand feeding systems remove fish farmers from this practice almost entirely, yet there is evidence to show that care is adapted rather than removed. The following extract explores on-demand feeding on a table production farm in the south of England:

As I walk to the bottom farm the high grass obscures any view into the ponds. What catches my eye is the appearance of large white buckets that appear to be levitating above each pond. As I draw near, I see that each pond has two buckets attached to a horizontal metallic pole that runs the pond's length, affixed to vertical support poles. Each bucket is free to slide along the pole with the aid of an attached rope. The construction is rudimentary, reminiscent of old scaffolding installations. It is clear from the overgrown site and the small number of discoloured and broken buckets situated in the grass that upkeep and maintenance are lacking. My attention is drawn back to the working buckets that are suspended over the earth ponds.

Fig 6 OxyGuard in use with demand feeders (Author, 2017)

Taking an OxyGuard, oxygen meter from his pocket, Jim (fish farmer) checks the ponds oxygen content, a quick glance at the display, and he's happy.

The working bucket feeders are drawn towards us along the metal frame by an attached rope, and we shovel buckets of feed into them. I notice some feed escaping the metal stopper at the base and pooling in the shallows of the pond. Jim is unbothered by this apparent waste of feed. Once full, the bucket feeder is given a forceful front kick to send the now full feeder sliding along the frame over the pond. Jim is away, tossing his feed shovel into the bin of feed pellets before moving it to the next pond. I linger for a moment to observe the interaction between fish and feeder. The fish swarm around the base of the feeder, their constant collisions with the suspended ballcock trigger the feed to spill out into the mass of bodies. The feeding hierarchy is pronounced the larger and dominant fish are packed below the feeder, aggressively thrashing as they feed. The smaller individuals are on the outskirts. This scene plays out with the fish farmer not present, my thoughts are drawn back to previous fish-feeding experiences. There are no sympathetic shovels of pellets directed to the periphery of the swarming mass on this farm. On this farm, the smaller fish must wait their turn.

There appears to be a number of similarities in the two examples of feeding through mechanisation and automation through on-demand systems. In both cases, the dwell time spent by the fish farmers at each pond is minimal. In comparison to the example of Simon's hand feeding, there is an apparent disconnect between fish and fish farmer. When elements of automation are incorporated, it would appear that the practice of feeding suddenly loses its skill and instead is downgraded to a simple task rather than an important and carefully executed practice. Indeed, the motivation of feeding in a manner that connections the farmer to the stock is lost as the fish farmer no longer has the opportunity to study and examine the stock during feeding. The fish farmer or junior member of staff must hurridly refill the feeders in a timely fashion before moving on to their next task. With this change of practice, the fish farmer loses a level of surveillance and oversight of the stock and the potential to spot biosecurity problems in their infancy before they can manifest into a farm-wide issue. The task is now easily thrust upon the junior staff, who may lack a seasoned fish farmer's trained eye.

Although convenience is a factor in forms of automation, it is also a case of necessity on larger table production sites. Where the volume of fish and the number of ponds and raceways are at a level where the staffing cost required to hand feed the fish potentially outweighs the profitability of such stocking numbers. Instead, larger farms may utilise scales of production to justify the investment in technology and machinery outside the realms of possibility for smaller farms.

The challenge is then for farmers to balance the utilisation of technological or automated systems of feeding while also attempting to retain the control and awareness of the condition of the stock due to the loss of surveillance with the adjustment to the feeding practices on site. A potential outcome of the loss of this daily surveillance practice removes a degree of care and prevention from the fish farming process. The inability to identify potential warning signs may lead to significantly more complex fish health and biosecurity issues that may manifest in the short to medium term. An example of the potential for a positive application of technology and automation is present in the example of oxygen levels before and after feeding. Oxygen demand and water flow are seen as a significant factor in avoiding fish health and welfare issues (North et al., 2006). Oxygen demand has been shown to spike post-feeding as the fish produce higher nitrate levels in the act of feeding and the digestion of the feed (North et al., 2006); (Alsop and Wood, 1997). Potential issues can emerge in the case of a fish pond that is already at a low oxygen level due to stocking numbers or a problem regarding flow rate is fed without first attempting to identify the ponds current oxygen level. Such actions have the dramatic effect of further reducing the available oxygen in the pond, and without immediate intervention from the use of aeration or oxygenation equipment, this can result in large scale losses due to asphyxiation. In the case of restocking farms, aeration equipment such

Fig 7 Paddlewheel (Author, 2017)

as paddlewheels are favoured while automated oxygenation systems are reserved for the larger table farms.

Fig 8 Oxyguard displaying oxygen content in water (Author, 2017)

In addition to these interventionist approaches, handheld oxygen monitors 'OxyGuard' can be utilised to monitor each pond prior to feeding. Where a pond is under a perceived oxygen threshold, feeding can be stopped for the day or until levels improve. The handheld monitors provide an accurate assessment of a key welfare parameter for farmers. Farms without such monitors rely on the skill set of the fish farmer to read the fish. A skilled fish farmer may read signs such as how high they are sitting in the water, style of movement and stocking density along with the environment, flow rater water quality to determine if feeding should proceed. The technology is expensive, with a single hand-held monitor retailing between £840-£900 (Sterner AquaTech UK). This economic limiter significantly reduces its availability and widespread use throughout the trout industry.

The potential benefits of new technology related to fish feeding practices are welcomed with regard to the accuracy of the equipment. What must not be lost through technological modernisation is the intimacy of the relationship of care between fish farmers and their stock. A notable reduction in or loss of this relationship of care has the potential to see the increase in disease and welfare issues on farms as the duration of dwell time at each pond is reduced, therefore the surveillance parameters of the sector now face an unforeseen consequence of modernisation. The skill of the fish farmer to view their stock and identify issues is not unique to aquaculture, it is a common feature among terrestrial farmers (Singleton, 2010:235). Singleton argues that caring for the farm network as a whole implies care for the life and welfare of its various constituent elements. In the case of a farm, care comes in diverse forms and formats varying from different production and feeding systems, availability and utilisation of technology.

The feeding behaviour of the fish exhibits the same power dynamics as alluded to by Harbers (2015:150). In the case of Harbers (2015) the hierarchy can be respected or breached in the case of the leader being kept away from a water pump to allow those animals further down the hierarchy to quench their thirst first. This dynamic is present in the strategic scoops of feed that are thrown to the edges of the feeding mass of fish. Habers further argues that 'caring well for the animals was not determined exclusively by us humans on the basis of elevated moral principles taken from animal ethics – such as welfare or fundamental rights. On the contrary, good care arose in everyday practice, in interaction with the behaviour of the animals themselves'.

It is clear that the practice of feeding is comprised of key elements which support and maintain the practice. Elements in this sense incorporate the model of social practice theory of Shove et al., (2012), in which non-human and material elements are included. Their importance is evident through the calculation of feed required to satisfy the appetite of the fish, the ability to monitor the oxygen content in ponds to carry out or adjust feeding schedules subject to the attentive eye and experience of the fish farmer. This section argues the benefits of automated feeding systems have the potential caveat of reducing surveillance of stock and therefore exhibiting a reduction of care on the site for perceived efficiency.

5.4 Interventions, vaccinations and disease mitigation

Preventative and interventionist measures have a significant role to play in the biosecurity of life on fish farms. From the onset of life on a fish farm, the life of an individual fish is precarious. Their health and welfare are directly linked to the care given through feeding, monitoring and treatment by the fish farmers. This section explores the interventionist approaches to disease prevention through the example of the Enteric Redmouth vaccine protocols. The vaccine protocols and the disease are introduced before being contextualised through fieldwork extracts of a day spent vaccinating juvenile fish on a restocking farm in England's southwest.

Caring for fish health and fish disease is a distinct element of fish farming. Commercial vaccine protocols prove an effective practice for reducing the threat of disease and protecting fish health. The favoured protocol is that of a dip vaccination, followed by a second booster that is administrated again through a dip or oral means and finally, the physical injection of the vaccine, which can be administered by hand or through an automated system (Brudeseth et al., 2013). Although the merits of this vaccination protocol are visible through strong and long-lasting protection throughout the production cycle of the fish, the vaccination protocol is not without negative aspects. Fish experience more stress, and the practice is significantly more costly financially but is also labour intensive (Embregts and Forlenza, 2016). Therefore although it is beyond the scope of this project, research is required to improve the vaccine protocols in existence from the perspective of reducing fish stress and reducing the impact on the aquaculture business. This research is effectively placed to critically engage with the practice of vaccinations as it relates to fish health and biosecurity. This is achieved by examining the use of the vaccine protocol for Enteric redmouth disease.

Enteric redmouth disease (ERM) also known as Yersiniosis is a bacterial disease which can affect both Atlantic salmon and rainbow trout leading to significant economic losses. Therefore, ERM presents as a central issue for global aquaculture. The disease was first identified and isolated in Idaho in the 1950s (Ross et al., 1966). In the following decades, the disease has spread globally to include South America, Europe, Australia, South Africa, China and the middle east (Tobback et al., 2007; Shaowu et al., 2013). The global reach of the disease and the ability of ERM to infect fish of any age, it presents more acutely in the juvenile fry and fingerling stages. This places it as an important disease within global salmonid aquaculture. The disease's effect on the infected fish can include changes in behaviour that may consist of surface swimming, lethargic movement patterns, and loss of appetite. Clinical signs of the disease include the darkening of the skin, and subcutaneous haemorrhages occur in the vicinity of the throat and mouth as gives rise to the name of the disease. Additionally, the spleen may become enlarged and darken in colour while the lower intestine can contain a yellow fluid, and necrosis can be present on the spleen, kidney and liver as shown in figure 9.

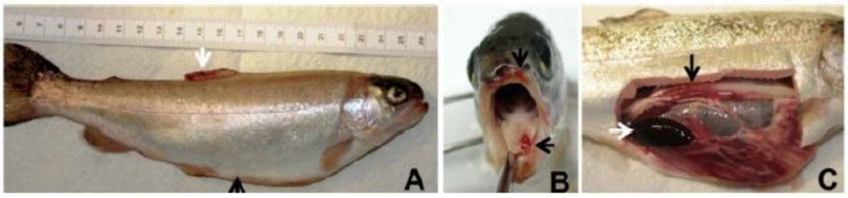


Figure 1 Rainbow trout showing clinical signs of enteric redmouth disease. A: darkening of the skin, *enlarged abdominal valley* (*black arrow*), and hemorrhages in the dorsal fin (*white arrow*). **B**: hemorrhages in and around the mouth (*arrows*). **C**: enlarged and black spleen (*white arrow*), and reddened intestine (*black arrow*).

Fig 9 Clinical signs of ERM (Kumar et al., 2015)

Transmission of ERM can occur through horizontal transmission from infected to non-infected fish. The disease has the ability to be carried in the lower intestine of up to one-quarter of rainbow trout without expressing clinical signs (Busch and Lingg, 1975). Instead, the bacteria are released when the host fish becomes stressed, through an increase in temperature etc (Hunter et al., 1980). The bacteria's ability to survive upwards of four months without a host is a testament to the challenge of effectively cleaning ponds and raceways (Busch and Lingg, 1975). Within the explanation of the symptoms lies a distinct link between host stress and prevalence of disease spread. At the same time, the reduction of fish stress is a key consideration of care and fish health within the industry. Vaccination procedures are a logical implementation of care against fish disease from Mol's (2008) perspective. There is room for tinkering between sites to determine the suitability of such procedures for fish produced for the table sector compared to the longer-lived restocking fish. Care in the form of vaccination is adaptable and logical, determined by the lay-expert, the fish farmer responsible for a site to adopt and implement.

5.4.1 Vaccinations in practice

What follows is an extract on the messy, frantic and stressful practice underpinning the biosecurity strategy of vaccinating juvenile trout against ERM.

After the morning feeding, we set about readying the equipment needed for the afternoon's task of vaccinating a population of juvenile fish on another local farm. I learn that the fish were initially sold from this farm, and as part of the deal, the vaccination of the fish was included at a reduced rate. The task is labour intensive and beyond the receiving farm's capabilities who operate with just one member of staff. The task will occupy three members of staff and myself to complete. It removes the staff from the farm for a half a day and is a significant drawn on the farmer's available labour. Our equipment is gathered, a large homemade table, piping, four injection guns, fresh needles and the vaccines bottles. Our equipment is disinfected and loaded into the crew-cab of the farm jeep for transport.

Fig 10 Homemade vaccination table (Author, 2017)

We spend the short ten-minute journey through the countryside talking about the task. The other fish farmers gain a little joy from explaining the agony of an accidental injection to one's finger. A fate that has afflicted Simon on two occasions, he does not recommend the experience! I bring up the suggestion of gloves for protection, and it's quickly shot down as being impractical when it comes to taking a secure hold of the fish. I take their advice and suppress a growing sense of anxiety when I learn that we will be vaccinating 30,000 fish, and my presence was key in getting the task done in due time.

We arrive at the neighbouring farm and are greeted by the owner, who is the only person on site. The site is noticeably more cluttered and messy in comparison to all of the other farms that I've been on. We set about our task of unloading our homemade vaccination table (Figures 10-11). The table is still wet from its earlier disinfection as we place it standing beside the concrete raceway containing the juvenile fish awaiting vaccination. The table is unique and unusual in its own right. Created from two old posters and some piping, the table seems both impressive and strangely overblown, until water is pumped through a generator and hose connected to the piping and suddenly the table comes alive with the flow of water through the piping and down and into the pond from which it came. Ciaran ties a line of string between two trees and suspends the clear plastic vaccination bottle over the table, while Gerry hands out protective eyewear. I stand with Ciaran, Simon and Gerry; two on either side of the table, and we ready our injection guns. The injection guns show a remarkable similarity to a tattoo gun. A clear plastic tube connects the suspended vaccination bottle to each of our guns. We test our equipment by pulling the trigger and seeing a minuscule amount of the liquid vaccine shoot out of the point.

Fig 11 Vaccination station (Author, 2017)

The farm owner retrieves a large net full of fish from the raceway; he submerges the fish in an anaesthetic bath for approximately ten seconds. The anticipation around the table rises as we place protective glasses over our eyes and await the farmer to place the freshly anesthetised fish on our table.

Once the fish land on the table the three men kick into gear with almost robotic efficiency, they quickly grasp, inspect, inject and release the newly vaccinated fish into the tables pipe network to return to the raceway. I observe the technique for a moment before the expectant glance of Simon spurs me into action. I awkwardly grasp a nearby fish. I am suddenly aware of my lack of dexterity as my fingers block the injection zone of the lower abdomen. I adjust, the fish slips from my grasp onto the table now lost amongst its peers. I hurriedly grab another fish as the pile is reduced by the skilled actions of the other men. This time I'm careful how I place my fingers. I flip the fish, so its abdomen is skyward and place the needle through the skin. I pull the trigger and release the fish into the pipework. The table is almost cleared as I inject my second and third fish. One table cleared other full net lands. The flow of water through the table system is a messy and leaky operation. Before long, we stand ankle-deep in the overflow water pooling at our feet as our environment becomes a hybrid of sorts, waterlogged and messy, yet retaining the structure and focus of the task at hand. I am now more confident in my new found skills, but this is soon tested as I lose control of a fish or rather, the fish regains consciousness and exerts its agency on this highly precise and controlled practice. The new stimulus of the fish suddenly resisting my grasp, wiggling and flapping in rebellion to this act of domestication as it struggles against this new unwelcome medium of air and human hands are enough to change the outcome at that moment. The fish slips in my grasp, and I stab myself in the top of a finger. I drop the fish in shock and somehow resist the routinised pull of the trigger. I am spared the full course of the injection but my finger slowly begins to go numb, much to the amusement of the other men and potentially the unvaccinated fish—a right of passage for all fish farmers and now me.

Within this extract exists several moments where care is present and important. The creative process of building the homemade vaccination table, a device distinctly created to improve the task's efficiency, facilitates care-practice in the form of vaccinating against disease. Combining the table design with the farmers' eager efficiency as they grasp, inspect and inject fish after fish, net full after net full, it is possible to see a form of the mechanised production line efficiency. However, focus, attention and skill are required to correctly place the needle in the young fish's abdomen, holding the fish in a manner that causes the least trauma to the fragile and incapacitated body. This extract shows the intrinsic link between the caring work of fish farmers and the overarching objective of maintaining a biosecure farm. Singleton's 'collective caring' (2010:244) is visible in this extract. The fish farmers have travelled to a neighbouring and downstream farm, that is linked by trade arrangements and the river course. Without the collective man-power of both farms, this vaccination practice would be impossible.

5.4.2 Beyond vaccination

While the practice of vaccination is underway there is a secondary, less visible task unfolding. Stationed on either side of the table are two large black bins placed between the injection stations. These bins serve a grim purpose. Lien refers to these fish as 'invisible deaths' or tapere ("losers") (2015:135). Lien's observation of the highly mechanised salmon industry's approach to vaccination is semi-automated and removed from the human non-human interaction experienced during the manual vaccinations of trout. Within the trout industry, the practice of vaccination is manually completed and labour intensive task relying on those undertaking the practice's accuracy and skill. A simple injection counter on each gun along with the generator pump is the only mechanised pieces of this operation. Lien (ibid) tracks the juvenile fish's movement along the automated production line from the anaesthetizing, movement on to the conveyer belt and automated injections. In many ways, a similarity exists in the timeline of both vaccination practices. However, the significant discrepancy exists immediately prior to injection. In the case of the Norwegian salmon, the automated process sorts the fish by size. In those instances when the machine identifies a fish that falls below a predetermined minimum size, that fish then encounters a diversion in the path to vaccination and instead, this nonconforming fish is released into a separate tank with other nonconforming fish to be later euthanised. This is done without human interaction but to a preordained requirement of size. The fish are destined to end their lives in this tank as they are seen as a burden on the production system and an excess cost of feeding. The same scenario is played out around the trout vaccination table. However, there are distinct differences in practice as this setting is removed from the semi-automated technology; the decision-making processes and agency reverts to the fish farmer.

I'm shown the sequence of movements required to vaccinate the juvenile fish. Injection gun in your dominant hand, reach and grasp the fish with the other. Placing your hand along its back, the fish is easily turned while remaining firmly situated in your hand. The importance of inspecting the fish is explained to me, it is very important to take a few seconds to scan the fish for deformities. The deformities of concern include a variety of physical issues including a cleft pallet, skeletal anomalies, severe fin injuries or missing fins, signs of debilitating skin conditions significantly undersized or fish showing clinical signs of disease. The fish farmer must process this mental checklist simultaneously to the act of injecting the fish. In instances where a fish is identified with one or a number of the conditions, that individual fish is dropped into one of two plastic bins located on either side of the injection table. When I raise the issue of uncertainty about what classifies as a non-conforming fish I am told by Simon

"just show them to me and I'll let you know, you'll get a feel for it".

(Simon – Fish farmer)

This tacit knowledge is of great importance to the practice of vaccinating fish. Removal of non-conforming fish has the potential to reduce disease spread through the removal of already stressed potential hosts from the wider population and reduce the financial burden on farms. There is prioritising of care from individual fish to population and farm viability. In this case, there is a strong argument that care is reduced for those individual fish that are non-conforming. Mol argues that 'care practices are resilient as well as adaptable' (2008:45). What exists in practice is a slightly more nuanced approach by farmers who may look favourably on the fate of non-conforming fish

I tend to always give them a chance

(Simon – Fish farmer)

Such flexibility has no place in the semi-automated salmon vaccination hut of Lien's (2015) experience. It reinforces the role of care within aquaculture and more narrowly within the practice of vaccination as fish farmers try to safeguard their stock from disease. This subtlety in such small moments of individualised care in practice offers a degree of flexibility that seems to be in conflict with preventative attempts to remove diseased fish from ponds in an attempt to limit the potential spread of the disease.

This account of the vaccination practice presents previously unaccounted for revelations of the use of tacit knowledge and farmer skill in challenging biosecurity practices. Additionally, the finding that such practices are not strictly adhered to is a poignant one. Trout farmers have been shown to use a degree of flexibility in making life or death decisions in a manner that does not exist within the tightly defined parameters of the rival salmon sector's mechanised vaccination practice.

Visible in the field diary extracts is the place of care in handling individual fish during vaccination and the optimism of giving the smaller fish a chance. This display of care is in juxtaposition to the placing of the un-conforming fish into the plastic bins to asphyxiate, a death sentence that appears to fly in the face of the practices of care that have been highlighted. However, as Mol (2015) has suggested, there is care in the act of killing. There is significant value in considering these moments of intervention, to leave an ailing fish in a pond or to remove that individual with the justification of preserving population health. The fluctuation of decisions relating to the future of the individual fish extends beyond management practices. Instead, would-be care better reflects those micro, momentary decisions that fish farmers encounter as they relate to life and death on the farm. This form of farming introduces challenges for care, not least in the visibility and identification of the individual fish from the collective. Differentiating the individual from the collective is a challenging prospect. Buller (2013:170) explores this challenge by introducing the question as to how far this cloak of massivity extends and at what point in the existence of an individual fish do we untangle the individual from what he describes as the mass or collective noun to become in the eyes of the human individual life in our affective relationality. In

Buller's (ibid) account, death is a marked point in time at which the individual fish emerges from the collective. Such moments as an individual fish is given a reprieve or dropped into the plastic bin illuminates the balance at play between the collective population health and that of the individual fish. In such moments the care is challenging and messy, tied to the survival of the pond, the farm and the industry. Care-practices within fish farming must be viewed as an integral element in doing fish farming well.

5.4.3 Disease management as care-practices – PKD

Disease management within trout aquaculture is not restricted to exclusion strategies and vaccination strategies as explored above. Intervention, prevention and management are all actively used strategies to reduce the impact of a given disease as detailed in Table 5.2.

Table 6.2 Mapping Intervention, Prevention and Management

	Intervention	Prevention	Management
Disease	VHS	ERM	PKD
	IHN	RTFS	RMS
Status	Notifiable/Listed	Endemic	Endemic
Action	Trade limiting sanctions, mandatory stock culls, movement restrictions	Vaccination protocols, treatment baths	Early exposure to reduce losses through disease resistance in year two. Antibiotic and disinfectant use
Result	The financial collapse of the business. Industry-wide disruption	Safeguarded stock. The financial outlay in vaccination and treatment costs	Minimal losses, Standard on-site practices required to maintain levels of disease management

Proliferative kidney disease (PKD) is one such example where fish knowledge and husbandry skill is paramount to avoiding instances of significant mortalities through disease management. PKD has been recognised as a parasitic disease of great economic significance to salmonid aquaculture. Although primarily regarded as a condition affecting first season rainbow trout, all salmonids can become infected during freshwater stages with varying severity. The name PKD was first coined by Roberts and Shepherd (1974) however, reports of a similar syndrome affecting trout date to at least 50 years previously. The disease is endemic in large areas of Western Europe and North America but has not been recognised in the Southern hemisphere to date. PKD is seasonal in nature, occurring when water temperatures exceed 15˚C, presumably in the summer and autumn months (Hedrick et al., 1993). PKD posses significant challenges for trout farmers in England and Wales, with sites acknowledging annual issues. For fish farmers, tackling an endemic disease is challenging as the feasibility of disinfecting farm sites is often impossible due to the nature of pond construction, water flow and labour shortages. Fish farmers must manage their stock through effective care-practices built on identifying key indicators of a potential outbreak, PKD is a disease which can be mapped directly on to increases in water temperature (Schmidt-Posthaus et al., 2012). The control of water temperature is often outside the influence of the fish farmer except for indoor recirculating systems, borehole or spring-fed production units.

5.4.4 Exerting Control - PKD

Where elements of control can be re-established is through specific husbandry or care-practices that have a notable effect on the spread of PKD. Attempts to tackle the issue of PKD on exposed sites through a process of assimilation have become widespread across the industry. PKD clinically presents on exposure in its first year. Fish farmers began to notice that juvenile fish who were exposed to PKD in their first year retained an immunity to the condition in their second year. Assimilation is a common practice on pig production units where the perceived gold standard of a pathogen-free and healthy stock is purposefully exposed to the pathological threats local to the site. Biosecurity best practice suggests that the movement of live fish and eggs onto a farm is amongst the most likely pathways for disease transmission (Oidtmann et., 2011). Therefore all juvenile fish scheduled to enter the farm site should be of good health and free from disease. However, fish farmers will strategically plan the delivery of new juveniles for the summer months when PKD is active.

> *"We do our best to get the juveniles in early so they get exposed, if we don't we could lose up to 30% next year and that's no good when you've spent the year feeding them. Sure we'll lose some on exposure but at least we'll know what we've been left with rather than wasting the money on feed."*
>
> (Eoin – Interview - Fish farmer)

Farms put a premium on this act of husbandry a built-in practice to combat an endemic disease that poses a significant economic threat to the industry. This method relies on intuition and husbandry knowledge to prepare for and prevent the onset of a much bigger disease issue at a time when the stock is required for production. It requires a strong knowledge of the site and strategic planning to coordinate the arrival of the new juvenile fish with the increase in water temperature and seasonal emergence of the disease. Fish farmers must balance the arrival of juveniles so as they are not late in the season and miss the exposure or too early and account for an increase in feeding expenses.

The ability of fish farmers to execute care through the management of PKD exposure mirrors the way parents exposure young children to chickenpox at an earlier age to lessen the potential suffering if the disease occurred in later years. Fish farmers must utilise their agency in conjunction with their tacit knowledge and experience to manage PKD, therefore doing care and biosecurity well.

5.5 Fishy Interactions

Beyond the previously explored instances of human- fish interactions of feeding and vaccination protocols examined in this chapter, there are a series of micro-interactions at play on fish farms across the country. The interactions are often routine and unremarkable at first glance from the fish farmer's perspective embedded in the industry. However, these moments of interaction between human and non-human extend beyond management practices and exhibit and reinforce the relationship of care shown to exist on fish farms. The following sections expand on the practices of care that extend to mortality (morts) removal, surveillance of fish and pests and finally, transportation of live fish on restocking and table farms.

5.5.1 Dead fish and mort bin

The mortality of stock is a feature of aquaculture. Through the scales of production involved with potentially thousands of fish in each pond and hundreds of thousands of fry in hatchery raceways, death is a far more visible feature of aquaculture production than a terrestrial agriculture production system, with the potential exception of intensive poultry production. When dealing with populations of such levels, the fish as an individual can be lost from sight through the constant flux that is the shoal of fish. There are no easy ways to identify the individual. The ear tags common amongst terrestrial agriculture operations are unsuitable for trout farming, as are other barcoding style mechanisms of surveillance. Instead, the individual fish are reduced to an 'undifferentiated multitude' (Buller, 2013:156), *'Pond 21', 'the fingerling pond' or 'the broodstock'.* Furthermore, the reduction view of the collective facilitates industrial agriculture. Buller argues that 'in their massivity, these herds and flocks become metaphoric and, as such, killable' (2013:170).

The following two extracts examine the practices of dealing with death, firstly on a table production farm and secondly, in the case of mortalities in a hatchery unit.

After the morning feeding, the staff split in two. One staff member proceeds with the task of investigating each of the thirty-two ponds and twenty concrete raceways that house the stock of rainbow trout. The investigation is in search of potential blockages on the inlet and outlet flows through organic matter, chiefly

Fig 12 Dead fish and Mort bins (Author, 2017)

foliage from upstream. Additionally, the fish which have died and risen to the surface, for the most part, exhibit the tendency to congregate on the outlet grates of ponds. With the flow of water often pinning the lifeless bodies to the metal grate that marks the pond's outflow point, the fish farmer must use a long-handled net to prise the dead fish from the clutches of the flow and capture it within the net in a quick motion. Some of the dead fish are less cooperative and evade the net as they're caught and swirled around in the water flow.

I join Richie for this daily ritual on a table farm. It is the middle of July and hot, with temperatures in the high twenties and water temperatures of over 17 degrees, the conditions are challenging for both fish farmers and the fish. Dotted around the outskirts of the ponds are a small number of large blue plastic containers. These large bins are covered with a lid that obscures our view of what is inside. However, as we draw closer, the smell being emitted from the bins leaves little doubt of the contents. They are the farms 'mort bins' where dead fish are stored before disposal. As we open the lid, we are hit with the most putrid and fierce odour. The air is hot as the bins have acted akin to a slow cooker, the dead bodies of the fish are in various states of decay from the freshly dead to almost liquefied, I am warned not to get any splashes of the liquefied fish on my clothes as the putrid odour is impossible to remove from clothes.

These large bins are emptied weekly and the contents processed through an incinerator located on a sister site, but for now, they are a testament to the fragile nature of life on the farm. We make our way past the bins and set about clearing the outlet grate of dead fish. I'm struck with how awkward the large net is to manoeuvre. Over 2 metres in length, I plunge the net down the angled gate into the pond attempting to dislodge the suspended fish from the flow reminiscent of a giant spatula. My initial attempts net most of my targets. A few fish escape my net and dance and swirl in the flow. It's challenging to capture these evaders as my net, now heavy from its load, is slow to react to my strain and I find myself intently focussing on these two particular trout that have broken from the masses in death. Upon retrieval, the morts are placed in the large bins for collection and incineration.

Unusually, there is no record kept regarding the number of dead fish in each pond. Instead, there appears to be the level of latent surveillance in action. Although mortalities for individual ponds are not recorded, there exists an understanding and a knowledge amongst the staff as to what is beyond the threshold for acceptable or expected losses. In the case where a pond is exhibiting worryingly high mortalities, the fish farmer who is tasked with the mortality removal passes their observations on to staff on the management level. Reporting of high levels of mortalities is done from one fish farmer to a site supervisor in an offhand, casual mention over the morning tea break. There is no formal documentation or paperwork. Instead, the information is shared and retained amongst the fish farmers responsible for the site.

The presence of the mort bins attempts to sanitise the farm by coordinating and concealing the daily mortalities. Lien (2015:70) introduces the fish farmer's dual role of both a caretaker and an undertaker, as the daily ritual of rounding up the 'daufisk' is paramount to hygiene amongst the larger population. Unlike the domesticated salmon farms, were the mortalities sink out of sight and out of mind to the bottom the sea pens before being agitated to the surface for collection and documentation, the mortalities on trout farms are more visible. The flow-through systems popular in England and Wales facilitate the posthumous journey of the trout to the outflow point of the pond where their bodies are pinned by the water flow against a grate. The suspension of the trout in the flow of the current provides a grim image of the fragility of life within aquaculture. In the many examples of care present in this chapter, there is the unavoidable truth that a fish farm will still suffer unexpected mortalities regardless of staffing levels, best practice methods, or technological advantages. There is a cost in the practice of fish farming. The fragile lives of the fish tied to the caring actions and practices of the fish farmers ultimately result in the deaths of individual fish. The cycle of care swiftly moves to the removal of the dead fish and striving to protect the remaining fish population against the fate of those newly deceased fish. The casual nature of mortality reporting on this farm is in stark contrast to a trout hatchery's practices. There is greater tension in providing acute care to the fish at their most vulnerable stage of life.

5.5.2 Hatchery accountancy

The level of care required to successfully operate a hatchery unit sets the building apart from other fish farms. Isolated indoors on a spring water source that is both reliable and stable in temperature, the newly hatched alevins and slightly more developed fry have an ideal environment to grow.

Disinfectant footbaths are located at the entrance to the hatchery and are mandatory prior to entry. The hatchery is the most biosecure location on the farm. In addition to the control of biological matter being transferred by humans via the footbaths, the hatchery's indoor nature stabilises year-round water temperature and reduces the risk associated with airborne and land-based predators. Mortalities in the hatchery unit are treated with a noticeable degree of attention and concern. The morts from each raceway are removed through a practice of gently sweeping the

Fig 13 Dead fry, awaiting counting and recording (Author, 2017)

raceways of faeces and waste products. This action helps move the morts to the outflow point where they are individually removed, counted and noted in a small notepad by Ken.

Within the hatchery, control is paramount. The fry's fragility and the concentrated nature of the hatchery's stocking density require a precision of care that is consistent and continuous. A failure in the pumping equipment left unattended can have the potential for the loss of tens of thousands of fry in a considerably short period of time.

“I live here, I'm always at hand if anything goes wrong”

(Ken – Fish Farmer)

“If the alarm goes off in the night I need to be up, incase the backup generator doesn’t kick in. Fish farmer’s don’t sleep very soundly”

(Simon – Fish Farmer)

Through these glimpses into on-farm practices of recording and accounting for mortalities, we can make sense of farming. Embracing the work of Law and Mol (2008) is fitting. In their exploration of actor-enacted sheep, there are parallels between the many expressions of sheep farming and fish farming. Viewing the individual sheep beyond simple economic unit value, and as part of a flock in a way that ‘drastically changes any assessment of slaughter. For there is pride in the history of breeding (selecting, caring) that goes into the raising of a flock’ (64). In a similar way, there is a craft and care at the centre of managing a fish farm, this is present in the hatching and nurturing of juvenile fish to those primed for sale or slaughter.

5.5.3 Nighttime surveillance

Fish farms are dynamic locations; in many cases, they are open sites, with the ponds and raceways outside the protective shield of a hatchery building. This sense of openness removes the complete nature of closure experienced by hatchery operators with their indoor systems of production. An outdoor site is a beacon for predatory wildlife, both terrestrial and aerial in nature, that might prey on the stock. The water level can be affected by upstream issues, floods, agricultural spillages or a build-up of organic matter that can pose a significant threat to the viability of the fish farms. These existential threats are not confined to traditional working hours but are omnipresent in fish farmers' minds. The following extract contextualises one fish farmer's actions as he attempts to safeguard a site through surveillance practices.

Shortly after 11 pm, a firm knock reverberates off the small cabin's wooden door that I am staying in. The cabin is located in the middle of the farm. Consisting of two rooms, it serves as a temporary home for seasonal workers. Upon opening the door I am greeted by the farm manager Simon and his dog. Simon is dressed in work trousers, sweatshirt and wellington boots. Under his arm, a shotgun held with the barrel broken open. As we begin our walk around the farm, Simon makes reference to the gun. "I've been seeing signs of predator visits to the bottom ponds over the last few weeks". Simon explains how he has discovered the bodies of fish appearing on the banks of ponds showing signs of predation, bite marks and missing heads. This directly impacts the individual fish that are lost to the nighttime visitor and severely stresses the remaining fish in the pond, which has been exposed to the disruptive and chaotic visit of the predator. Herons and the occasional otter are of primary concern on the farm. Simon admits that although it is annoying to lose the occasional fish to these nighttime predators, he is more concerned with the elevated stress levels of those left behind.

It is clear that the purpose of this walk is that of surveillance. We quietly walk around the perimeter of the farm with the ever-alert cocker-spaniel at our feet. Running along the boundary of the farm is a miniature electric fence. The fence stands no more than 30cm tall and is easily navigated by humans or energetic dog. The fence appears relatively new and well maintained. I'm told that is proving an effective measure against otter incursions. We are greeted by some sounds of wildlife that emanate from beyond the beams of our head torches. Our walk around the farm's perimeter is without incident and we see nothing untoward.

Fish farms must contend with a variety of predation concerns. In the case of Simon's farm, land-based predators such as otters are most concerning. In this example, the nighttime predators generate a dangerous trend among the fish stock. A pond that is targeted by an otter may lose one or two fish a night but potentially more concerning is the impact on the stress levels of those fish remaining in the pond. Heightening the stress levels creates a demand for oxygen within the pond and places the fish in a heightened state. It is an established fact that fish who experience an elevation of plasma cortisol levels brought on by acute stress results in an increase in mortality due to common bacterial and fungal diseases (Pickering and Pottinger, 1989). Airborne predation is problematic for large sites with low staff numbers as herons prey on fish stocks in abundance. This species of bird is protected under the Wildlife and Countryside Act 1981, which proves problematic for fish farmers as shooting licenses are limited. Netting at significant cost along with timed noise charges are used to ward away the birds, yet losses are unavoidable. This protective presence adds another dimension to care in aquaculture. In this case, there is stewardship in protecting what is perceived as valued life and emphasises their absence and exclusion through barrier systems and lethal interventions. It is not just the threat of predators that require night-time patrols.

We are careful not to venture too close to the trout ponds, from our vantage point we quietly observe the ponds which appear docile and tranquil. We turn our attention to the water inlet and outlet points. During the summer and particularly autumn months foliage and organic matter from upstream sources find their way into the farm's water system. A poorly clogged inlet can significantly reduce water flow into the pond and cause a drastic increase in stress levels amongst the population of fish that are starved of oxygen. Simon quickly clears a metal inlet grate which is half covered in leaves. Pointing to a nearby tree which overhangs the neighbouring pond he identifies the source of the leaves.

“I would love to get rid of the thing but the fish like the shade and its nice spot during the day”.

(Simon – Fish farmer)

As we make our way through the dark to the main inlet flow on the farm Simon directs my attention towards a water gauge.

"The entire farm is alarmed, if it backs up during the night, I'll know and I'll be out, same with the hatchery if the generator goes down I need to be there in minutes or else we're in trouble!"

(Simon – Fish farmer)

It is clear that securing life on a fish farm extends beyond the 8 am to 5 pm workday, the practice is on-going and without a clear conclusion. For Simon and other fish farmers across the country, there will always be a fish population dependent on their stewardship. Although the threat of disease is a worry, too is the danger of sudden water and oxygen circulation issues caused by faulty equipment or environmental factors such as flooding, drought or organic matter.

5.5.4 Transportation

The movement of live fish from fish farm to fish farm or fishery posses a number of issues within aquaculture. Oidtmann et al., (2011) have identified live fish and egg movements as the most concerning pathway for disease spread between infected farms and new outbreaks through the application of a risk-based disease surveillance strategy. The risk-based surveillance protocol in compliance with the European Council Directive 2006/88/EC (Anon., 2006) is further discussed in Chapter 6. This section examines the actions of fish farmers and fish engaged in the practice of transportation. Transportation of fish requires specialised

Fig 14 Specialised transport vehicles

equipment. A restocking farm in the southwest of England operates two specialised trucks that house water tanks and oxygen monitoring equipment and aeration to ensure the fish's health and condition throughout the transportation process. The larger truck holds three separate water tanks capable of allowing multiple site deliveries per trip, while the smaller truck houses one tank that may be separated in two if required. Both vehicles are equipped to transport fish across England and Wales. With an annual production of 120,000 fish for restocking, a secure and reliable delivery practice is essential to the business.

Regulations on the transportation of live fish are in conjunction with the European Council Regulation EC 1/2005 (Anon., 2004) is the basis for live fish transport policy. The following extract details the process of preparing two deliveries of approximately eighty matured trout. The fish are to be transported to a fishery in the same county to restock an angling pond.

It’s two days before the delivery is scheduled, and I find myself attempting to net a pond of fish for sorting and grading. Working in a team of three, we tighten our net around the entire pond before slowly pulling to the bank. The fish are crammed together and their heightened activity isn’t lost on the fish farmers. I’m tasked with delivering a net full of between six and ten rainbow trout between 1.3kg and 2.2kg to a shallow bin situated between the two farmers. The men quickly select each fish individually, remove it from the water by their hands and visually inspect the fish. If the fish passes this visual inspection and meet a size requirement, it is placed in another larger bin as the fish farmer audibly counts the number of fish. The men work in tandem and the process is efficient. There are no checklists for this task, not visibly at least. Each fish farmer relies on experience to determine the fish is fit and healthy enough for transport and they conform to the order weight. The tension and activity of the holding net dissipate throughout the sorting and grading. After each batch of fish is sorted they are placed in two raceways to await their forthcoming transportation. The raceways are restricted from feeding for the day and a half before transport as the stressed fish tend to excrete in the transportation tanks and jeopardise the quality of the water.

This very process of handling and grading fish is a highly stressful experience. Krasnov et al., (2005) report alterations to the brain and kidney function linked to handling stress. Yet it is deemed a necessary procedure on this farm. There is a process of weighing up the pros and cons of this practice. The staff are experienced and aware of the potential detrimental health effects caused by this practice yet seem accepting of this task as unavoidable while relying on their efficiency of skill in minimising the duration of time the fish must undergo this practice.

The customer order requested four large trophy fish. These particular valuable fish are located in a special pond which holds the largest and oldest fish on the farm. The task of selecting the four fish and moving them to the raceways is identical to the earlier sorting and grading. However, the actions of the fish farmers and their attitude to this particular task were worthy of note. I'm told the large fish have a tendency to be more fragile and the speed of movement is critical. We place a black bin, three-quarters full of water near the pond. Gerry and I take our positions, either side of the bin with our backs to the pond facing the raceways eighty metres away. We stand ready to act on Dan's mark. Dan is using some feed pellets to attract the large fish close to the bank. He identifies his target and with a swift plunge of the net he lifts the fish to out of the pond. He quickly places the net on the grassy bank and administers a dye injection, marking the fish as a trophy fish on the customer's request. The fish is placed in our bin, and we set off. Our hurried pace is reflective of our precious cargo. I occasionally glance into the bin to check on the condition of the fish. As the water sloshes around the fish is clearly stressed, it moves with the water almost semi-conscious, potentially in a state of catatonic shock. I glance back to our route and try to spot any potholes or any other change in terrain that could trouble our journey. We approach the raceway and instead of placing the fish in the communal concrete unit, we swiftly but carefully empty the bin and the fish into *the attached pond. The fish reacts to this new settle medium and appears to be unaffected by our archaic and hurried form of transport. We repeat this practice for the other trophy fish to the same conclusion. One fish shows signs of being unresponsive when placed in the new holding pond. The fish farmers are understandably worried as they watch the fish rigid and on its side. Gerry takes a nearby net and uses it to nudge the fish upright, which seems to spur the fish into life. Simon is notably apprehensive and mentions keeping an eye on them throughout the night.*

Balancing care-practices and fish welfare between the profit-making objective of the business muddies the waters in this extract. It is questionable if trout of such ‘trophy size’ would mature to such a size and age in the wild, as reflected in their fragility during transport. Although the fish are exposed to the ordeal of movement there exists within the actions of the fish farmers a sense of purpose and duty to the fish that far exceeds their economic value and this complexity of the

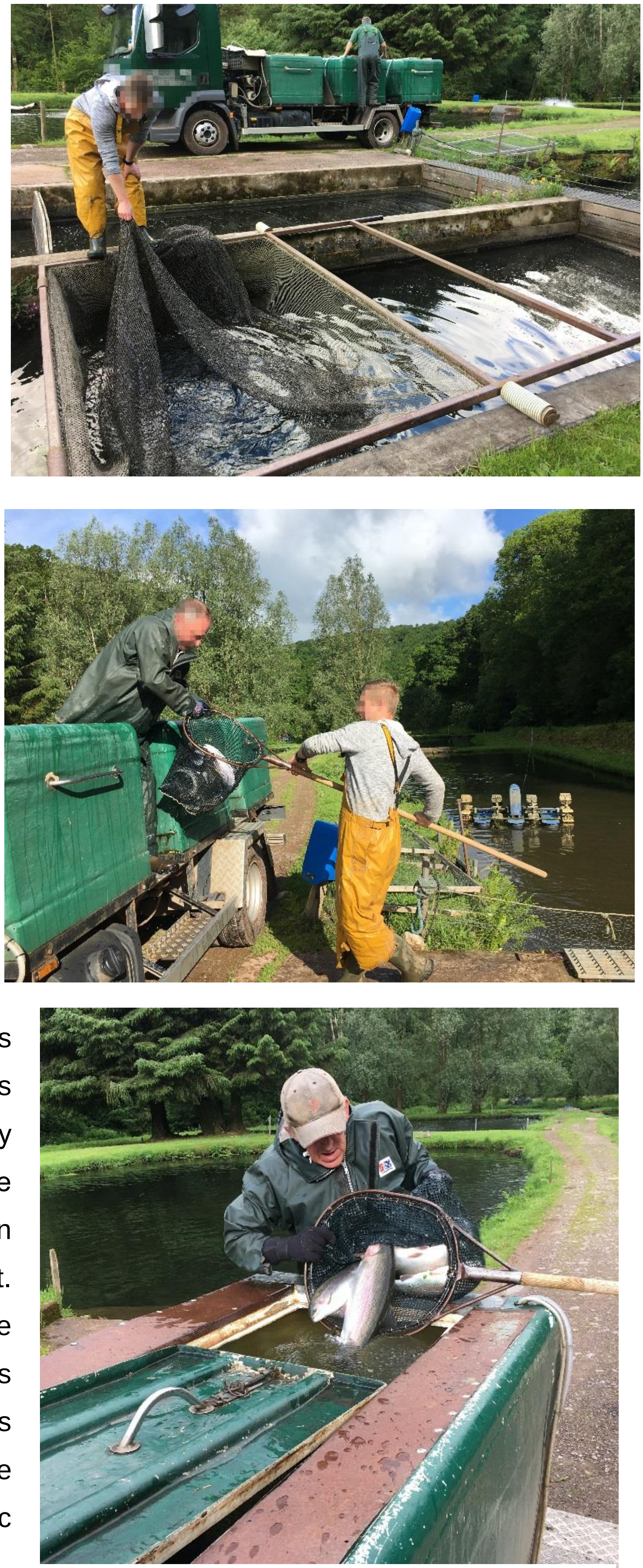


Fig 15 Three stages of loading fish for transport (Author, 2017)

fish farmer – fish relationship proceeds to make this practice however far from ideal, workable.

Delivery day. The smaller delivery truck is parked alongside the holding raceways. We fire up the generator and start to pump pond water into the storage tank until it is half full, leaving Archimedes' principle of the soon to be loaded fish.

Gerry and I work in tandem to deliver net full upon net full of trout to the awaiting Ciaran who loudly counts each fish that goes into the two tank compartments. With the fish loaded the oxygen tanks set to open we clamber into the cab. The farm manager hands Ciaran a movement certificate and invoice for the deliveries. We make a quick check on the oxygen meter inside the cab with the corresponding display on the tank and we set out on our way. No more than five hundred metres from the farm entrance, the truck pulls over to a layby. Ciaran climbs out of the cab and sets about disinfecting the vehicle, the wheels, wheel arches, the steps into the cab and the onboard nets before finally spraying the disinfectant on our wellington boots. Upon arrival at the fishery, we are greeted by the owner who assists us in the unloading. The fishery owner offers us his nets but Ciaran politely refuses, instead opting for the onboard nets that have been known to have been disinfected earlier in the day. With the fish unloaded and the movement document and invoice exchanged we depart for our second delivery of the day. Pulling in at the nearest layby, we repeat the disinfection procedure for a second time. It is noticeable that more care is taken this time in comparison to the earlier attempt.

"I know that our farm is clean so that's really just for show. I don't know what they have here so I'm being careful. I'll clean the truck again before we get home, you don't know what might be brought back on the wheels or wherever, you can never be too careful"

(Ciaran – Fish farmer)

The actions of Ciaran during the delivery process are some of the firmest examples of conventional biosecurity and disease prevention actions. Distinguished boundaries between farm and the outside world are respected and all efforts are made to sanitise the equipment and vehicles leaving and entering the site.

Throughout the accounts of the lesser-known or valued embedded practices, there is the presence of interspecies care between human and the non-human. The practices that have been experienced are absent for the most part the use of mechanised technology. In fact, it can be argued that the practices of caring for the dead and caring for the living through the night and in the transportation are distinctly complex insofar as the disturbance and handling of the fish. Even the task of removing the morts is carried out in a way to limit the disturbance to the remaining live fish by focusing on the removal of those dead fish that have become trapped in the outflow of the pond. The common trend among these practices is the attempt to reduce the level of stress experienced by the fish, even in instances where stress is unavoidable. Amongst fish farmers, stress is perceived to be a major threat to the health of the population (Pickering, 1992). Amongst the most striking comments from a fish farmer was on the fragility of life.

'Fish die for fun'

(Simon – Fish farmer)

This is a striking and powerful statement that truly highlights the fragile balance that is life on a fish farm. The fish farmers in control of this environment are responsible for balancing fragile life and the external pressures of operating a profit-making enterprise.

5.6 Summary

This chapter has investigated and demonstrated the presence and the role of care practices that are of critical importance in securing the health of farmed trout and the health of an entire industry. Care practices have been shown to go beyond husbandry and prove to be an integral part of biosecurity on farms (Higgins et al., 2018). Forming the basis of this chapter, the first-hand experiences of the embedded ethnographic experiences on fish farms support the argument for the importance of the relationships of care that exist in both the visible daily actions and practices of fish farming and the invisible nuances and cadences that exist in the interwoven lives of fish farmer and fish. At this point in the thesis, it is appropriate to reflect on practices of care as the emergent and dominant conceptual framework from chapter 5 onwards. Although the emergence of practices of care as a key concept was assisted by the earlier work of social practice theory to identify the particular farming practices, practices of care will have a more substantial contribution to the concluding chapters and the key deductions of this research.

This chapter also examined some of the key practices of aquaculture and their role in providing care on the farm. Singleton argues that good farm practices as being passed along generations (2010) as practices are learned through doing and as sets of continuities. Farming practices may be *done* rather than known or told they may be *silent and implicit* rather than explicit and verbal (Reckwitz, 2015). The two examples of feeding and vaccinating explore the complexity of what appears to be the simple task of throwing feed pellets into a pond by positioning the feed at the centre of the aquaculture network. With specific legislation on the availability of certain feed ingredients in the form of LAPs/PAPs and feed companies' role beyond that of simply supplying consumers with a product.

Vaccine protocols for ERM were examined along with the lesser-seen judgement calls on life or death for juvenile fish, furthers the inter-species relationship that emerges through the ethnographic fieldwork. Life on a fish farm is a balancing act of fish numbers vs oxygen availability, caregiver vs would-be predators, which are among some of the dynamic and changing challenges faced at farm level.

By examining each practice that has been identified through practice theory, in its very minutia, from the toss of the feed into the awaiting hungry pond to the frantic pressure to quickly and effectively examine and vaccinate juvenile fish during the manual ERM vaccination days, it is apparent that beyond the slow creep of mechanisation and automation into certain aspects of the industry, what remains a constant is the skill and knowledge of the fish farmers who are guardians of the industry, their stock and their individual livelihoods as tied to the sustainability of their fish farm. This exploration argues for the multiplicity of care and how farmers care for their farm as an enterprise and their stock as an essential element of biosecurity. Singleton supports this perspective and points to the presence of care in 'rituals and mechanisms of repetition that are embodied, located, and responsive to [farmers'] livestock, their land, their family and themselves' (2010:250).

Fish farmers occupy a caring role that remains detached from the troublesome pitfalls of problematic care experienced by Giraud and Hollin (2016) where displays of too much care threaten staff effectiveness. This chapter has uncovered the importance of the human – non-human relationships of care that are currently under threat through erosion by mechanisation and automation. Care practices require a greater focus for their role in developing on-farm practices of what Higgins et al. (2018) call biosecure care. The overarching sense of personal investment in the care of these aquatic animals comes to the fore in the hurried acts of transporting fish between ponds and the concern of the fish farmers for the welfare of the individual fish, admittedly a fish of significant economic value to the business. However, the same fish farmer displayed patience in the face of adversity when faced with the decision on the fate of the undersized juvenile fish awaiting vaccination or culling. It can be argued that rooted at the centre of aquacultural businesses are the individual fish farmers who, through experience and personal investment, are tied to the role of caregiver to a population of fragile, domesticated fish, utterly reliant on the decisions and practices of the fish farmer. This responsibility goes beyond the financial viability of the business to include the responsibility of ensuring the welfare and health of the fish for the duration of their lives on the farm. Yet it has been documented that the industry and those in the role of a caregiver are often calculated and clinical in their actions, the case of the non-conforming juvenile fish left to asphyxiate and the night-time patrols with the intention of killing a troublesome predator presents a duality of personality and feelings towards animal life. Care has been framed as something mundane and tacit, an inevitable part of scientific research (in the case of Giraud and Hollin, 2016) or, in this case fish farming. There is a requirement for constant negotiation and tinkering to accommodate the systems of commerce and production with which there is an uneasy relationship. Whilst good care does not assume a prescriptive form. It nonetheless relies on the willingness of the fish farmers to exhibit and openness to affective encounters. As Mol argues, it ‘threatens to take the heart out of care and along with this not just its kindness but also its effectiveness its tenacity and its strength’ (2010:7).

6. Surveillance, Monitoring and Inspection

The actions of securing biological life through disease management practices of good welfare, attentive farming, quarantine procedures, vaccination and post-exposure treatments rely primarily on the ability of those tasked with securing life to accurately and promptly identify issues at or just prior to their initial occurrence. For this to become an achievable goal in any food production network with an emphasis on trade, a robust strategy of surveillance must be in place. Commonly, such strategies conform to the established biosecurity paradigm of sanitation, surveillance and organisational integration (Hinchliffe et al., 2013), as discussed in chapter 2. Within aquaculture, Risk-based Surveillance (RBS) facilitates trade from countries or regions of a biosecurity or disease status to others with similar or lower levels of biosecurity and disease status. The suitability of this approach and its application to biosecurity within the trout aquaculture industry demands further examination.

This chapter will; 1) Introduce Risk-based Surveillance (RBS) and provide a contextual background to the legislation underpinning this form of surveillance; 2) Examine the implementation of RBS within the context of the trout aquaculture industry in England and Wales; 3) Provide in-depth field reports on the implementation of the strategy in RBS. This will be accomplished through ethnographic research conducted on a number of fish farms through the active shadowing of UK Fish Health Inspectors during their scheduled annual monitoring visits to fish farms and aquaculture production businesses. This exploration into the regulatory field builds on the practices of care that were developed in chapter 5. In this chapter, the focus turns to care for an industry. The relations between fish health inspectors and fish farmers proving noteworthy with relevance to Mol's (2008) 'logic of care' where considerations are made as to what is appropriate for a particular site at a given time and what is not appropriate or logical to implement.

6.1. Introduction

To understand the foundations of regulation within the food industry it is worth considering the work of Marsden et al., (2010), who present perhaps the most detailed review of the evolution of the UK's food governance structures. The three identifiable stages of governance range from pre-1980s when agricultural systems were deemed intrinsically safe and the state occupied a key role in the food supply sector. The first evolution identified by Marsden et al., is the transition away from government-led regulation and monitoring that was facilitated by regulatory, environmental health and trading standards officers. Zwanenberg and Misstone (2003) are critical of this stage's ability to respond to BSE crisis that the UK endured. This era witnessed the rise of large retail multiples' food chain management and food standard strategies (Hinchliffe et al., 2017:144).

The second evolution can be viewed as a private-public regime. This consisted of the state continued to operate spatial regulation for retailers and non-corporate producers while the private sector attempted to regulate the supply chain. For Marsden et al., (2010), this stage is defined by the role of large retailers as policy drivers while the state operates in auditors' role. Marsden et al., acknowledge that this stage did see increased levels of assurance. There was still elements of the supply network unaccounted for.

The evolution to the third stage reported by Marsden et al., occurred in the aftermath of the BSE episode that dominated the UK meat industry. The findings of the James Report (1997) and Phillips Report (2001) prompted a shift of governance from the farming lobby, producers, and large retail operators to one that shifts the responsibility of food safety onto a new policy formation network that combines; 1) private interests; 2) policy and regulatory interests; 3) consumer and social interests. The trout sector operates within these parameters. Fish farmers face demands from large-retail multiples on issues of fish health, welfare and reliability of supply. Producers must meet these demands to retain the financially important supply contracts. Additionally, producers must conform to the Fish Health Inspectorate's biosecurity demands to operate legally.

6.1.1 Risk-Based Surveillance

Establishing and maintaining structures of disease surveillance and control are an intrinsic part of global trade. Cameron (2012:280) argues for the importance of accountability as ‘domestic disease control programs and international trade increasingly rely on veterinary authorities' ability to confidently demonstrate that populations (herd, zone or country) are free from disease or infection’.

Regulatory pressure currently extends from Brussels to all aquaculture businesses across the European Union in the form of the European Council Directive 2006/88/EC on animal health requirements for aquaculture animals and products thereof and the prevention and control of certain diseases in aquatic animals (Anonymous, 2006). The Directive calls for the organisational integration and the implementation of surveillance protocols. Moreover, the Directive requires a risk-based surveillance approach to biosecurity in aquaculture. At this point, it is important to define both risk and RBS.

Risk has several connotations in everyday usage from the chance of failure, loss as covered by insurance, speculation in investment finances, the chance of injury, amongst others. Within the context of this work on biosecurity, the notion of risk is specifically aligned with its definition in epidemiology: ‘the probability of disease developing in an individual in a specified time interval’ (Rothman and Greenland, 1998:40).

RBS is prominent in veterinary medicine and veterinary public health. Stärk et al. (2006:4) offer the definition of RBS as ‘a surveillance programme in the design of which exposure and risk assessment methods have been applied together with traditional design approaches to assure appropriate and cost-effective data collection’. RBS is noted by leading aquaculture researchers within Cefas as a surveillance method that takes into account the probability of a hazard, its consequences, management and perception to detect cases in a population or sub-population (Oidtmann et al., 2011). The application of RBS is wide-spread in other major food-producing industries including Danish pig production (Alban et al., 2008); shellfish (Thrush, 2017); dairy (Whist et al., 2014) and beef (Nöremark et al., 2011).

RBS is a method of engaging with the problematic nature of emergent life. As predicting the future of problematic life can be a complex challenge, Collier (2008) argues that historical records are of little reliable use in predicting future events and new methods to calculate future events must replace traditional methods of statistical reasoning. Braun (2013) tempers this opinion through the examples of known biological risks within food-borne diseases such as salmonella and e-coli that are well known and are largely mitigated through a series of agriculture and food production practices. However, there is perhaps a middle ground that acknowledges the existing indeterminacy. As modern agricultural and aquacultural assemblages change, so too do the transmission points and new contagion come to the fore as viral and bacterial life is never stationary, always prone to mutations (Braun, 2013), (Wallace and Kock, 2012).

This risk-based approach to surveillance seeks to implement a degree of accountability between regions regarding a particular area's disease status. Mumford (2013) argues that ‘the aim of risk management is to achieve an acceptable level of risk, not necessarily to reduce risk to zero (2013:107). Oidtmann et al., (2011) acknowledge the Directive aims to improve aquatic animals' health while facilitating trade. The aquaculture industry aims to increase the flow and circulation of valued life and capital across local, regional and international borders that allow a trade to flourish under a risk-based surveillance approach to biosecurity.

There are considerations regarding RBS that must be identified. Stärk et al., (2006) are clear that risk-based surveillance systems offer a more efficient approach for early detection and management of diseases, and an increased level of efficiency compared to other surveillance options such as risk-based sampling. The later is a modelling approach that has been utilised in environmental sciences to provide early warning or cost-effective surveillance to predict sites that have the potential to become contaminated. They also stress the importance of international cooperation as innovative methods of risk-based surveillance can only be established if there is agreement on both the methodology for risk-based surveillance and the interpretation of any results, in essence, the standardisation of accepted methods of measurement.

Furthermore, Mumford's (2013) alternative and perhaps more nuanced view on risk profiling and its failure to justify additional management practices for established risks are significant. Chapter 4 of this thesis examined the views of fish farmers regarding the individual and types of diseases that impacted their livelihoods. The overwhelming sentiment that fish farmers are more concerned about diseases under Mumford's (ibid) explanation is accepted and well established. This invites questions as to who is being served by a risk-based approach to biosecurity. It is acceptable to argue that the presence and persistence of endemic and frequently-occurring diseases can be viewed as less problematic and not a risk for trade. While trade is proven to be facilitated by this approach to biosecurity, chapter 4 and the accounts within this chapter offer a strong argument that fish health at farm level is unaffected in the main by national level biosecurity policy. This chapter argues that the existence of potentially destructive non-native diseases on mainland Europe have little impact on the everyday practices of an English or Welsh fish farmer beyond industry and FHI updates. For fish farmers, the perceived distant nature of this perceived threat weakens its position in the hierarchy of risk within their daily lives. This potentially problematic approach to disease echoes geometrical disease networks that Hinchliffe et al., (2013) argue to be ill-suited to conceptualise disease, instead favouring disease topologies. The FHI plays an important role in identifying risk and drawing the attention of fish farmers to it, effectively, there is the potential do develop a discourse of risk to generate preventative actions from fish farmers.

6.2 Inspection and Auditing

Risk-based surveillance within the trout industry of England and Wales is the calculable and cost-effective targeting of key sites and production processes to assure compliance, or as Stärk et al., (2006) put it the allocation of resources effectively and efficiently. Together it addresses two distinct objectives: 1) compliance with an external governance regime; 2) maintain economic productivity on sites and safeguard the industry's sustainability. It is the surveillance protocol of choice stemming from the European Council Directive 2006/88/EC. What follows is an investigation of the practical application of this form of surveillance in the field. What are the interactions between the agents of the state responsible for statutory surveillance and those fish farmers whose operations are surveilled? What are the latter's attitudes to the legislative requirements of inspection and auditing of records? These questions will be addressed through the shadowing of what are the on-the-ground manifestation of RBS, the annual monitoring visits by the FHI. Although RBS is utilised remotely to identify and determine the most cost-effective allocation of surveillance resources, it relies on the monitoring and auditing of the collected data to accurately protect the industry. However, these visits are not strictly data collection moments. Inspector visits are transactional. While the inspector collects critical data, they are engaged with farms for several hours and knowledge and experience on the industry trends are passed between inspector and farmer in a mutually beneficially form. These moments of knowledge transfer places the FHI as a valuable resource to fish farmers, yet these occurrences are viewed as a secondary aspect in field inspections.

The shadow visits include each of the different production locations and stages of trout aquaculture (hatchery, restocking, table producers and an initial inspection visit to an aquaponics unit under construction and application of license). The following sections will describe and analyse the performance and practice of annual monitoring visits as the key manifestations of RBS, bringing the Fish Health Inspectorate and fish farmers together to interact both on-farm and at a distant.

6.2.1 Fish Health Inspectorate and Surveillance

The Fish Health Inspectorate is the agency of the state directly responsible for the enforcement and surveillance of aquaculture in England and Wales, with a particular emphasis on the surveillance of exotic and notifiable disease incidents. It is of key importance to this chapter to effectively place the FHI within the industry and acknowledge their operating strategies. By understanding the role of the FHI the biosecurity and surveillance landscape within aquaculture is more clearly visible.

The inspectorate operates from its base in the Cefas laboratory in Weymouth, Dorset. The inspectorate comprises of a dozen field inspectors. The field inspectors are tasked with the surveillance of all aquaculture production (freshwater finfish and shellfish) sites in England and Wales, responding to reported cases of suspected notifiable disease outbreaks or unexplained mortality incidents on fish farms and commercial fisheries. In addition, the FHI facilitates customs control of live fish movements via international transport hubs. The inspectorate encounter freshwater trout, carp, ornamentals, along with shellfish species as part of their duties. Recruitment for fish health inspectors' positions is strategic in so far as to recruit individuals who have previously occupied roles within the aquaculture sector. The Inspectorate retains a core of individuals with over twenty years of experience and is overwhelmingly male-dominated. This is not uncommon for the trout industry which appears to attract a majority male workforce. The Inspectorate's stability is noteworthy, as the level of disease-related knowledge in the group is an essential requirement for the functionality of this agency of the state. The complexity of fish health issues requires an extended training period for a new inspector, which can last between 18-24 months and includes the shadowing of senior inspectors during the inspection and annual monitoring procedures. This extended training period in conjunction with the complexity of the disease issues, makes the recruitment of former fish farmers a logical strategy. Current members of the inspectorate remark on the stability of their positions within the FHI in comparison to their previous employment on fish farms, as job security within aquaculture is rare for all but a few.

The operational areas for each inspector consist of 2-3 counties. With clusters of fish farms located on important river catchments such as the Avon, inspectors' geographical spread reflects the location of fish farms. The inspectorate seeks to create a balance between a familiarity between fish farmers and their assigned inspector and novelty through a policy of planned rotation of inspectors. This practice encourages the inspectors to undergo a planned rotation of their areas of responsibility approximately every four years. This tactic helps to create rapport between the inspector and the inspected while also acknowledging that this relationship requires a periodic refreshment with the rotation of the inspector to maintain a degree of authority and regulatory detachment. The strategy the FHI uses to resolve contentious issues is two-fold. Firstly, upon identification of a serious issue that may require enforcement action, the inspector tasked with the farm in question and presumably the one who identified the issue is removed from the case. Secondly, a senior inspector who specialises in enforcement actions is assigned to the case. This approach is most recently evident in the case of the 2006 VHSV outbreak (Stone et al., 2008). This approach allows for contentious issues to be handled by highly experienced and respected figures within the industry while safeguarding the regional inspector's relationship with the farm in question.

The first-hand experience of the practicalities of day-to-day life on a farm is an essential component in an inspector's skill set. Embedded in each inspector is a degree of understanding for the fish farmer's position in their efforts to prevent or control the spread of disease on their farm. The feasibility of actions and the worthwhile nature of such actions vary distinctly from farm to farm. Merely conforming to a perceived best practice approach to biosecurity may not provide the most return for the input of valuable resources such as time, labour and money. Hinchliffe et al., argue that biosecurity is an ‘ongoing compromise between economic circulation, the regulation of surplus life and the organisational requirement to make life safe’ (2017:48). For farmers to be successful, decisions must be made on biosecurity strategies that will be effective on the farm. It is then the task of the inspector to utilise their knowledge and experience to make judgement calls on farming practices in a manner that is sympathetic to the challenges of dynamic production operations and the overall biosecurity mission of the FHI.

Additionally, fish farmers are aware that each inspector has first-hand experiences and learned knowledge of the industry. For them, the presence of an agent of the state who has intimate knowledge of the industry's complexities and practicalities may offer a greater sense of support while also inadvertently discouraging attempts to hide or deflect information relating to their farm. This serves as an introduction into the dance of regulation and surveillance that will now be expanded upon as a key interaction between the state and the industry through the medium of participant observation via the shadowing of inspection visits carried out.

Managing an RBS approach requires the adaption to and utilisation of technology. The System for Tracking and Recording Fish and Shellfish

(STARFISH) helps the FHI carry out its responsibilities to disease control in the English and Welsh fish farming industry. The system provides a register of fish farms and businesses and monitors stock levels, production, movements, imports and exports. The system's practical applications include the management of agreed schedules for inspections of fish farms. It manages the inspectors' workload, generates pre-visit documentation and all correspondence, records all samples taken by the inspectors. The system utilises an iPad app for regulatory visits to fish farms which is fully integrated with the main STARFISH database.

6.2.2 Annual Monitoring Visits

Every aquaculture production site in England and Wales is legally subjected to a minimum of one physical inspection known as an annual monitoring visit by the Fish Health Inspectorate each calendar year. The visits are announced, and the dates are scheduled in advance with the farmer for the coming winter months. Annual monitoring visits are scheduled during winter as the warmer summer months brings increased pressure on the FHI resources due to the prevalence of disease outbreak events on both salmonid and carp farms and fisheries. By scheduling the annual monitoring visits to trout farms in the colder winter months, the Inspectorate can ensure they have the physical resources to respond to disease outbreaks when called upon.

A subsequent inspection can be scheduled for farms exhibiting particularly poor fish health and welfare behaviour. Oidtmann et al., (2011) acknowledge that inspection frequency must consider the likelihood that a particular fish farm may contract and or spread disease due partly to that farm's characteristics (proximity to other farms, high frequency of stock movements, etc). When a trout farm is categorised as particularly at risk of the potential spread of disease through fish movement, production style, or substandard onsite practices, additional measures may be implemented. Several identifiers mark strategically important fish farms within the entire industry. Farms that are involved with breading and hatching juvenile fish to sell to other farms have the potential to be at the epicentre of a disease outbreak. Similarly, those farms operating a business model reliant on the trade of live fish to fisheries are also uniquely positioned to facilitate the spread of an outbreak to multiple catchment areas. For Oidtmann et al., (2011:330) 'the design of RBS requires epidemiological data, in particular, risk factors for disease occurrence' (e.g. strata of a population, or farm systems, in which the disease is more likely to occur). The model utilised by Cefas and the FHI account for risk factor themes: live fish and egg movements; exposure/spread via water; processing plant on-site; geographical factors (flood risk); mechanical transmission.

These tactics of surveillance seek to correlate fish movements between farms. In the event of a disease outbreak, movements of infected fish and the disease itself can be traced back to a source population and from that source population to potential other sites that have been exposed to the disease through the movement of infected fish, equipment or vehicle movements.

Currently, the industry has little to no exposure to the threat of key diseases such as VHSV or infectious haematopoietic necrosis virus (IHNV), yet these remain a viable threat when seen through the lens of disease topologies (Hinchliffe et al., 2012). What occupies uncertainty within the industry is the presence of endemic diseases and their importance. They are the most concerning for fish farmers yet are not seen as so important by FHI via the RBS lens. Mumford (2013) suggests that allocating RBS resources to endemic threats is not justified. This perspective is challenged repeatedly during discussions with stakeholders who strive to defend their stock from endemic threats.

As discussed in section (3.3.4), field inspection procedures can vary from site to site to the style of operation (table, restocker, hatchery) and from the personal style and experience of the inspector, allowing for variability in the sample inspections. Some factors remain constant as the FHI will attempt to trace movements of fish off-site and prescription medicine usage on-site. What follows is an account of the announced annual inspections that occurred in 2017.

6.2.3 Inspections in the field

As we approached the farm entrance, we pulled our car into the staff carpark located outside the main farm site, within a clear view of the office and operations building. The inspector, Mat, a former fish-farmer with a speciality in trout farming, opens the boot of the car and retrieves an outdoor jacket embroidered with the

FHI logo, which he dons before retrieving several additional items from the car, a tablet enshrined in a heavy-duty protective casing. For all inspectors, the tablet has replaced the paperwork created by each annual monitoring visit. Once a cumbersome and repetitive exercise for field inspectors, the tablet and advancements in technology have assisted the streamlining of the task of reporting of visits and reducing the duplication of records from inspector notes to the FHI database. Mat is happy with this advancement of technology as it reduces the duplicate workload of reinputting information upon returning to the Inspectorates offices in Weymouth. In addition to the tablet is an Oxyguard; this handheld device can provide information on water temperature and dissolved oxygen content in seconds through an attached probe that is dipped into the water body in question. The penultimate addition is a pair of polarized sunglasses. What remains in the car boot is a copy of the farm's layout and current biosecurity plan used by Mat to familiarise himself with the farm prior to arrival. Before donning our wellington boots, we take care to disinfect the boots using the chemical Virkon via a hand-held spray gun. This act beyond its objective to prevent the incursion of pathogens onto the site is also a form of ritual and performance:

‘We always make a point of parking off-site and disinfecting our boots for all to see. I’ve already disinfected them this morning but it’s good practice and it looks good’

(Mat-Fish Health Inspector)

We are greeted at the boundary gate of the farm by the site manager. Before entering the site we lift the lid on a footbath which we intended stepping through to find it empty with a noticeable crack in the base. Our host sheepishly apologises and remarks how he’s already seen us disinfecting our boots and we continue on to the site.

Our host is keen to facilitate our visit and asks if we want to tour the site or go to the office first. Mat chooses the tour and we set off around the extensive site. Our host first walks us through the feed storage shed and onto the locked medicine storage cabinet. He narrates the scene, recounting the investment in the site over *the last few years to create the secure storage of medicines and feed. During this time, Mat asks some questions relating to the handling and mixing of prescription medicines. The tone of the conversation and general interaction between the two is friendly, almost jovial in places, and it becomes apparent that the farmer and inspector know each other from the inspector's past role as a fish farmer. The men ask about mutual acquaintances in the industry and how they're doing. Mat answers these enquiries in a friendly but measured way, without revealing specifics on particular farms.*

From the outset of this encounter, the inspector engages in what we might identify as a biosecurity performance. By visibly disinfecting our boots in clear view of the farm office, there is an attempt to develop trust between the inspector and the farmer. It is a pertinent example of a biosecurity practice. Inspectors are known to visit multiple farms a day, potentially acting as a pathway for spreading a pathogen (Oidtmann et al., 2011). Reassuring a fish farmer that the individual responsible for the biosecurity audit is adhering to best practice is important. Additionally, the wearing of a branded jacket and the accompanying tools of a tablet and oxyguard monitor empowers Mat with the full authority of the FHI. As the two men clearly know each other from Mat's previous role as a fish farmer, this subtle distinction of power is important for the inspector to retain control throughout the inspection process.

This interaction is important to consider; the isolated nature of the industry limits the fish farmer's experiences and interactions with other fish farmers. Visits by the FHI allow for information gathering by the farmers.

As we walk along the long row of ponds the farmer explains aquaculture business's nature, large-scale table production in earth ponds. Fish farms of this style large sites with earth ponds have distinct interconnectivity. The flow of water through the farm makes the site into one large interconnected body of life. A site of this size relies on a low stocking density to compensate for a low flow rate of water that moves throughout this expansive collection of ponds. By their nature, earth ponds are porous and subject to decay, bank erosion, and collapse. Ponds have been known to seep into each other through tunnels created by rats and entire segments of the bank to disintegrate and allow unwanted fish movement *between ponds. In this sense the ponds' communities although distinctly known by their pond number, share a physical connection with other ponds across the site so the concept of separate communities of fish operating within one network is accurate only to stocking numbers. We identify a small number of ponds that lie fallow and empty of both fish and water; we are told the ponds are under repair.*

On occasion, we pause by a pond as Mat flicks the polarized sunglasses down over his eyes to better view what is happening below the water level. The inspector is assessing the fish's movement and behaviour, both as a population and as individuals. By attempting to view the actions and movements of a pond's population, he can gain an appreciation of the level of stress and stocking density present in the pond. Key indicators such as sudden and sporadic movements and fish congregating close to the surface or water inlet suggest that the fish are being exposed to a stressor or the pond's dissolved oxygen level is low. In the instance of a low level of dissolved oxygen, the farmer may take one or a combination of steps to alleviate the problem and increase the welfare of the fish. These steps can be a husbandry matter of reducing feeding schedules for specific ponds, to artificial actions such as turning on rotatory paddle wheels if applicable adding oxygen to the pond via a network of gas pipes, 'mushrooms' (floating spheres capable of releasing oxygen into the water) which are connected to an oxygen silo. The action that is taken is linked to the economic security and size of the aquaculture operation. Smaller sites may lack the capital investment to include an oxygen system and must, in turn, rely on the husbandry skills of the fish farmer to reduce feeding when appropriate and control stocking densities on site. The farmer who until now has been chatty, slowly allows the conversation to drop as his gaze is drawn to the observations of the inspector and for the first time, there is a notable degree of tension in the air.

The inspector's eyes, now hidden under the polarised lens, are focusing on the individual characteristics of the fish within the pond. Characteristics or behaviours that draw the attention of the inspector can include unusual behaviour by individual fish, isolation away from the main population, changes in pigment, difficulty swimming, skin lesions, swelling or obvious signs of skin damage from parasites and predators. These traits are not easy to identify, particularly from our *position on the bank and allowances are made for a population in the thousands for a small number of weaker individuals. For now, Mat seems content and moves on from the pond and conversation picks up.*

The inspector's judgement on this comes through practical experience on sites as to what is considered normal or explainable and routine. What then remains are cases where mortality or disease events are unexplainable and out of character for the site; it is these events that trouble and occupy the FHI. Similar to the inspection process described by Lavau and Bingham (2017:24) the inspector must pay attention to the different aspects of the farm from ‘its records and marks, its people and practices, its infrastructure and its animals’. The actions of Mat to engage with the water, the environment, the fish and the fish farmer portrays the inspector's ability to adopt with different modes of attention, in what Lavau and Bingham (ibid) describe as ‘a dynamic, inter-sensorial, bodily engagement with the inspector's surroundings’. The balance of importance across the aspects of records, people, infrastructure and animals is not equal in an RBS approach to biosecurity. Necessity dictates that the records and marks are the most important aspect of the entire inspection procedure.

As we conclude our site tour, Mat comments on the site's positive actions in the last twelve months (since the previous inspection) to reduce the ingress of avian predators through the erection of a netting system to protect the fish from the threat of herons. The farmer acknowledges that while there was a significant cost to the erection of the netting and the acknowledgement that the avian predators do still have the capacity of circumventing the nets their impact on the fish population through the loss of numbers and stress has been significantly reduced. Before moving into the office Mat takes a moment to dip the Oxyguard device into the water to record the water temperature on-site, a mandatory task that must be completed. The readings show water temperature to be in the high single digits. A reading that is expected for the time of the year and well within the parameters of normal for the site and for trout farms in general.

Throughout the farm tour, the mood between the farmer and the inspector has been relaxed and casual with the underlying tiered relationship between the surveillant and the surveilled is present and a factor in both individuals' behaviour.

There is a notable change intact upon entering the office as the farmer is asked to produce movement, mortality and medicine records for the time between the last FHI visit and today for an inspection. It is at this moment that I am struck by the change of pace in this inspection. As the farmer opens a filing cabinet to retrieve the requested documents, he is asked to retrieve a movement record from a date over four months ago. As the farmer hurriedly scans the movement records to provide the inspector with a corresponding entry in the farm's record-keeping to show the movement of a population of fish, it is clear that the previous farm tour and visual inspection was merely a preamble to this moment. This shift in focus and pace has evolved this inspection into an audit. The documents are identified and the movements match the farmer's records. This style of task continues with treatment usage until the inspector has matched several fish movements to individual populations and ponds of fish and treatment usages to prescriptions. In this instance, the inspector is mimicking the actions of a disease containment team following an outbreak. If the inspector is unable to trace the population of fish or is unsatisfied with the condition of the farm's record-keeping, the likelihood of movements being successfully tracked in the event of a notifiable disease outbreak is unlikely.

While observing the audit phase of the inspection, as each document is requested and located, it is apparent that the operational protocols for monitoring and recording stock, movements, and prescription medication usage are presented in a clear and obvious manner to those tasked with operating the site. Documents are filed and recorded in an easily searchable manner, while invoices are clear and obvious to decipher. The structure allows for the elimination of most of the questions that may arise about the documentation and surveillance of stock on other farms that operate less structured record keeping. In a surveillance approach of this kind, the inspector must perform the majority of the inspection in the site office and with ever-increasing paperwork. In such visits, there is a disjointed aspect that Lavau and Bingham (2017:28) describe as a snapshot, a momentary encounter. This snapshot, by necessity, redirects the attention of the inspector and the FHI as a whole to the record-keeping competences of the farmer.

6.3 Planning and Control

Within the finfish aquaculture sector in England and Wales, the most distinctive document available to fish farmers and other stakeholders with direct reference to biosecurity in aquaculture is the 'Finfish Biosecurity Measures Plan: Guidance and templates for finfish farmers and traders' (Fish Health Inspectorate, 2009). As each farm is required by the Aquatic Animal Health (England and Wales) Regulations 2009 to complete one, with the guidance of a fish vet, and maintain an up-to-date edition, the document is one of the most widespread sources of information and guidance on biosecurity and farm management practices. The introductory paragraph clearly identifies the parties responsible for safeguarding the industry on all levels from farm level upwards,

'The application of biosecurity in aquaculture is a shared responsibility, where each individual involved plays a different but critical role in the implementation of the overall programme. In order to be effective, biosecurity is necessary at all levels within the aquaculture industry, from control of the spread of infectious disease at an international level, to the development of national controls and down to the operation of suitable practices at a local level. In these terms, the World Organisation for Animal Health (OIE) monitors the international status of diseases, our government (through Cefas) is responsible for controlling biosecurity within national limits, and Aquaculture Production Businesses (APBs) are responsible for biosecurity within their enterprises' (ibid).

The text opens with the narrative of collective responsibility, Donaldson (2013:63) credits the development of the policy and regulatory framework for the UK's biosecurity on 'a long and disjointed history of interventions in agriculture, principally around animal health'.

The biosecurity farm plan advises an eight-step course of action for farms as they put into place the necessary roles, relationships and practices required for the establishment of a unique biosecurity measures plan suitable for their farm. In terms of creating a culture of on-farm biosecurity, the eight steps include:

1) **Appointing a biosecurity manager;** this step is potentially the most significant. It identifies an individual, usually, the farm owner/operator or

the farm manager who has the responsibility of ensuring the biosecurity measures listed in the plan are in operation on the site. Additional responsibilities include organising and facilitating the training of staff on biosecurity issues to include the regulation of visitors to the site while maintaining effective record-keeping ability. In essence, this individual is the contact point for the FHI during annual monitoring inspections or disease outbreak events. Designating an individual with whom responsibility rests allows for a relationship of trust to develop between the responsible individual and the FHI operating in that area. This relationship is valuable to ensure timely reporting of suspected disease issues and the likelihood of mutually beneficial communication between the FHI and the fish farmer. In cases where operations are small, the biosecurity manager by default will be the farm owner or most senior member of fulltime staff.

2) **Veterinary health contracts;** building on the role of the newly appointed biosecurity manager is the establishment of a relationship between the farm and a veterinarian professional. The strong relationship between farm and a specialised fish veterinarian is valuable. In the case of the large table producing operations, a specialised fish veterinarian is often placed on a style of a retainer and will answer disease-related queries and authorise the use of prescription medication in cases that warrant medical intervention.
3) **Providing staff training in fish health management and disease recognition;** the guidelines suggest that staff training should be viewed as 'continuous learning rather than a one-off exercise'. This approach suggests that the nature of biosecurity is an ongoing and unending task is captured within the industry mindset. By highlighting the importance of identification of risks as a fundamental part of operating a fish farm, the opportunity to facilitate training in knowledge and identification of clinical signs of disease, along with training in the 'host susceptibility and the range of environmental parameters that could precipitate clinical outbreaks'. In addition to setting out the guidelines for training, a list of sources of information on fish diseases is listed, along with an example of training of staff to identify clinical signs of disease.

4) **Identify the risks of contracting and spreading disease through fish movements;** this point is a direct manifestation of the work of Oidtmann et al., (2011), who determine that live fish movements on to fish farms are one of the greatest risks of disease spread between farms. The guidelines are sympathetic to the industry's nature and provide a series of considerations for fish farmers to undertake if the movement of fish or eggs onto the farm is necessary. The document provides farmers with an eight-point checklist to consider. The checklist includes ‘disinfect eggs before incubation and dispose of the packaging in a sage and biosecure manner’ and ‘if possible, isolate introductions of fish from other stocks until their health status can be established’. The phrasing of these points emphasises the diverse nature of challenges facing different farms. Each fish farm must account for its own risk variables as determined by the fish farmer in charge. Additionally, the use of a practical example allows farmers to contextualise the issue of disease movement through new stock.
5) **Identify the risks of contracting and spreading disease as a result of site procedures;** suggestion five returns to the on-farm actions and procedures that directly impact the likelihood of disease occurrence. In many ways, this point of pausing to identify what distinct risks (presence of disease spreading vermin, shared equipment and vehicles) are applicable to each individual fish farm site allows fish farmers to actively engage with their site and identify the potential risks stemming from equipment sharing procedures, the restriction and control of third party access to the site.
6) **Risk limitation measures;** From the point of identification, a procedural approach to controlling the identified risks can be undertaken to include the zoning of different farm areas to limit the transfer of stock, water, equipment and biological life between these areas. In essence, the building blocks for a form of securitisation of the site. Additionally, the inclusion of ‘It is the biosecurity manager’s responsibility to ensure these measures are implemented and regularly monitored for compliance’ again reinforces the role of the biosecurity manager as the individuals with

responsibility and the ongoing nature of the traditional forms of biosecurity surveillance.

7) **Monitoring the plan;** The inclusion of a template to aid the newly appointed biosecurity manager, who may or may not have any experience in the recording of key information. The FHI provides the following examples of information that warrants recording; 'stock health inspections, visitor details, disinfection producers, other useful biosecurity information to be recorded'.
8) **Contingency planning;** The final stage of the biosecurity plan focuses on what happens after the initial identification of a problematic disease. The identification of the importance of contingency planning encourages fish farmers to develop a protocol or indeed a set of protocols known by all staff to react to varying disease issues, including recognising a disease or parasite, what to do regarding unexplained mortalities, measures of control and the disposal of dead fish.

The Biosecurity Measures Plan may appear like a historical document, one to be drawn up as part of the farms' establishment, a charter or contract of operation, this is far from the truth and far from the purpose of the document. The document is a living entity, flexible to adjustment and change. It offers value to both the fish farmer and the FHI. As part of the annual monitoring visit, the inspector is required to review the plan, noting any adjustments to the farm or the farming practices. The plan is shared by the farm and the FHI and acts as a link between annual monitoring visits.

The document offers the inspector a valuable preview of what to expect prior to inspection. The legislative requirement for such a plan acts as a material technology of attention and effectively translates and condenses the policy requirements and assists the inspector in distributing valuable time during an inspection.

"I had a look over the biosecurity plan last night, it helps to look at it in advance to get a feel for the site"

(Mark – Fish Health Inspector)

The Biosecurity Measures Plan is a form of guidance rather than a strict set of protocols. The plans are site-specific. Similarities exist between plans around fish movements and treatments. If farming practices evolve, there is an expectation that the document changes to reflect the farming practices. During the shadowing of one annual monitoring visit, the inspector raised the practice of resupply of juvenile fish from multiple sources. The farmer quickly pointed out

'We don't do that anymore, all our fish come from our own hatchery in [redacted site name]'

(Shane – Fish farmer)

The inspector with agreement from the farm manager notes this change in the farm's biosecurity measures plan and updates the FHI records.

In some instances, the role of the document as an adjustable tool is lost as farmers will attempt to highlight their efforts to conform with the biosecurity measures plan in the presence of the inspector when the evidence suggests this is a token effort to tick a regulatory box, the detailed explanation to follow in (6.4) highlights the attempt to perform biosecurity. In this example, the fish farmer attempts to display his biosecurity practices unrealistically in order to mirror the farm's biosecurity plan while it would be more pertinent to adjust the plan to reflect the daily farm practices. This plan facilitates the ability of the primary fish farmer or biosecurity manager to carry biosecurity practices. However, an ill-suited individual lacking the competence to engage with and utilise the plan may simply relegate it to a filing cabinet awaiting an annual review by the FHI.

6.4 Surveillance

There are underlying questions on what effect the biosecurity measures plans have on the everyday operation and daily practices at the farm level. Although all fish farmers are required to have an up to date biosecurity plan on-site as detailed in the Aquatic Animal Health (England and Wales) Regulations 2009, there exist conflicting examples of daily on-site and what the farmers have aspired to carry out in the plans. This section explores the tension between what is documented in the biosecurity plans and the practical representation of farming practices. Dip stations provide a useful demonstration of an ingrained practice and the traditional infrastructure of biosecurity.

Fig 16 Designated farm footwear and disinfection station at the perimeter of a fish farm (Autor 2017)

Dip stations became synonymous with news reports on the countryside crisis of the Foot and Mouth outbreak (2001) and the manifestation of biosecurity in the UK as the practices of cleansing and disinfecting the countryside and the control of movement across agricultural assemblages (Donaldson and Wood 2004; Hinchliffe, 2001; Law, 2006). Over time, the maintenance and refilling of the dip stations can see farmers ignore the practice as too time-consuming, or in some cases pointless, as visitors are infrequent, and the only people on site are staff members. These perspectives are entirely valid and the Fish Health inspectors acknowledge that the daily use of these stations on some farms does not occur but for the most rigidly operated sites and hatcheries. Inspectors have noted that farmers will put foot dip stations out for annual inspections in an attempt to impress the inspector. This regulatory dance between fish farmer and inspector, as demonstrated through the following extract of an annual monitoring inspection in 2018, is noteworthy.

The following field report of an annual monitoring visit to a small restocking fish farm highlights ineffective biosecurity practices.

Fig 17 Disinfection footbath complete with weather cover, strategically placed outside the door of a hatchery. (Author, 2017)

Prior to the visit, Mark the inspector explained that this farm is somewhat evasive towards the annual monitoring process, with previous accounts of junior staff members being left to answer questions that should be fielded by the farm biosecurity manager. There was an air of scepticism to what we might encounter as we approached the farm.

Fig 18 Disinfection bucket, filled with tools designated for hatchery use only. (Author, 2017)

Upon arriving at a multi-location rainbow trout operation, we are greeted by the farmer who is busy netting a pond of fish with another member of staff. After a brief introduction, we are told that due to a staff member being off work due to a back injury, the fish farmer was a bit behind in his daily schedule; it was clear that the fish farmer would rather complete his *netting task before dealing with the inspection. Mark can see this and interjects with the suggestion that we can* *do a walk visual inspection of the site (Site A) before driving the short distance to the other site (Site B-same ownership) where we will repeat the visual inspection process before returning to site A to inspect the movement records and other farm-related data when the fish farmer has completed the netting task.*

During our unaccompanied walk around the site A, I note the overgrown nature of the site. Mark agrees with my observations, noting that although entirely superficial, the trimming of grass banks and trees on fish farms is a good marker of site maintenance practices. Our walk is sporadically and frequently interrupted by Mark who pauses at different ponds to assess the liveliness of the fish contained in the ponds; he points out potentially troubling clinical symptoms on some fish. As our walk develops the change in his body language is obvious; he is visibly annoyed.

We stop at one pond. It contains approximately 6 visible dead fish; the mortalities have notable fungal issues on their skin, and a number of the remaining live fish share these issues. The inspector vocalises his annoyance at this pond:

'This is really not good enough. The fungal infection is a secondary condition so they're stressed with something else'.

(Mark - Fish Health Inspector)

As we walk the farm, we can see evidence of predator proofing in the form of ground-level electric fences aimed at deterring foxes, otters and other land-based threats. Along with this new addition to the site the earthen ponds were covered by netting to protect against aerial predators. The netting was in disrepair and easily breachable by predatory birds. Banks were overgrown in areas and the site. Although annoyed at the condition of the farm and free to speak freely away from the farmer, Mark acknowledges the farm is understaffed and there is a limit to the ability of even the best fish farmer to operate a site with limited staffing. Later, the condition of the observed fish is gently raised as one the fish farmer should be attentive to.

Although the farm walk element of the inspection does little to reassure the inspector that biosecurity on this farm is a priority, there is a realism in the mind of the inspector. Although irritating and less than satisfactory, there were no instances in which the Aquatic Animal Health (England and Wales) Regulations 2009 were jeopardised. In this case, the instances were more husbandry and fish welfare rather than strictly a biosecurity concern.

While on the tour of the site, the fish farmer, upon completing the netting task located and filled a soft plastic laundry bucket (similar to that of Figure 17) with disinfectant. Upon returning to the farm entrance, we notice the bucket and the frothing suds along with its obvious placement. After the inspection, I raise the dip station's appearance with the inspector, who remarks that in all likelihoods, the farmer had placed the station to conform to his biosecurity plan, which lists dip station as a biosecurity measure. The inspector remarks how he could have simply removed the dip stations from the biosecurity plan but raising that option to the farmer after seeing the dip station could potentially lead to conflict upon the suggestion that the practice was merely a once-off for the benefit of the inspector.

In this example of a site that occupies a precarious position regarding the husbandry of the site and stock, the farmer's thought process to hurridly deploy this rudimental and blatantly temporary feature reflects how biosecurity is envisaged on some fish farms. The dip station is symbolic in the minds of the public through evocative images of livestock culls and intensive countryside biosecurity assemblages (Donaldson and Wood 2004). This example reinforces the attachment and the dip station's position in the biosecurity paradigm is maintained at least symbolically. The farmer is attempting to demonstrate to the inspector that they are, in their minds taking biosecurity seriously by illustrating compliance with the Biosecurity Measures Plan. In this case, such attempts to game the system of biosecurity governance relegate their meaning into symbolic or procedural gestures. The inspectors must be constantly vigilant of such attempts to circumvent the intention of the system. The prioritisation of this action over husbandry practices brings forth the question, why do some farmers seem to miss the intention of the biosecurity measures plans? This is can be attributed in part to the need to pass the annual monitoring visit, (Bingham and Lavau, 2012; Lavau and Bingham, 2017) at the expense of identifying why particular practices are absent on the site through the lack of competence, materials or meaning (

Shove et al., 2012). In the case of this farm, a more nuanced approach to the husbandry of the site and the updating of the biosecurity measures plan to reflect what is within the means of the operation to achieve would potentially satisfy the gut feeling of the inspector while demonstrating the regulatory requirements of movement records and medicine use that are integral to the annual monitoring visit. The following account moves the inspection indoors to accommodate the checking of movement records and to update the biosecurity plan.

We conduct the data collection phase of the inspection in a secondary kitchen located adjacent to the fish farmers home. The inspector facilitates the inspection by following the biosecurity farm plan as a guide. Throughout the inspection, the farmer is constantly on the move, coming and going from the makeshift kitchen area where we are seated to his home and returning with tea bags and coffee before leaving again and returning with milk. This action, coupled with the farmer's body language of standing instead of sitting giving the impression that our presence is an inconvenience. When questioned on the movement records the farmer produces from his pocket, a handwritten list of names and months on the back of a small sheet of paper. The sheet appears to have been hastily transcribed and this is later confirmed when the farmer is asked for the previous six months to which he states;

"she's (referring to his wife) just writing them out now"

Almost brazen in attitude to the importance of tracking the movement of live fish from the perspective of the FHI, it becomes clear that his movements to and from the kitchen area were a means of gathering the information that he anticipated requiring to appease the inspector. Mark avoids this potential moment of conflict by introducing the fish farmer to a new mobile app that can log all incoming and outgoing fish movements and updating in real-time, linking back to the FHI network, thus doing away with the need to keep the physical records.

This approach to surveillance and inspection is at odds with the following account that features the same FHI (Mark) and a similar-sized fish farm.

With the guided farm tour complete, we enter the farm office. On one wall a series of licenses, awards and notices are arranged in neat order. The office contains two corner desks, a laptop, desktop and printed along with a collection of coloured folders. Mark begins the now-familiar audit phase of the inspection by working through the farm's current biosecurity plan. This strategy allows the FHI to retain the most up to date info on the industry. When asked about fish movements, the farmer is quick to produce a folder containing a printout of all fish movements off-site in the past year. When questioned on the location of the supplied movement book, the farmer is apologetic in stating the farm transport vehicle is on delivery and the book is kept in the vehicle. This instance is an example of the fluid nature of data records. There is no set requirement for farmers to use the provided stationery to record fish movements. The existence of stationery is to promote the practice of recording. The inspectors are sympathetic to farmers recording movements in a manner that suits them.

"It doesn't really matter how they keep their records, just as long as they do it accurately, that's the important thing"

(Mark – Fish Health Inspector)

This data sheet is cross-referenced with the inspector's tablet to match recipients of fish with the FHI record of fisheries and other farms. Some confusion exists where recipients are referred to by another name or title to what is available to the FHI to select via the tablet. In total, the inspector is able to match all fish movements off the farm for the year in approximately fifteen minutes. I am left in no uncertain terms that this farm and the practices embedded in its daily operation represent a good practice model for the surveillance of fish movements with both the inspector and fish farmer being prepared for the inspection.

The openness and organisation of this farm are striking in comparison to the previous example. Together they contrast the challenging nature of capturing reliable data in the field. Inspectors are tasked with compiling data to the best of their abilities, yet the records' reliability is dependent on the fish farmers themselves and their understanding of and engagement with biosecurity.

During the farm encounters of annual monitoring visits, there are education and assistance occurrences that extend beyond a traditional audit or inspection. In essence, such educational encounters are as Lavau and Bingham (2017) suggest ‘attempts to shape future possibilities for care’ (2017:29). The dual role of assisting and enforcing is documented in the role of the environmental health officer in work (ibid). There is a similarity for the fish health inspectors within the aquaculture industry. In the case of movement records is an example of an attempt to improve the practices there is flexibility demonstrated by the inspector to deviate between ‘enforcer and advisor’ (Lavau and Bingham 2017:30). Indeed such visits can leave a ‘legacy of care’ that extends beyond the visits as fish farmers may take on some of the suggestions into their on-farm practices as they move along what Bukowski et al., (2012:2) describe as a pathway of compliance.

6.5 Future Challenges for Biosecurity Surveillance

The future of the biosecurity measures plans is uncertain, with many questions remaining on trade requirements in light of the UK’s departure from the EU on the 31st of January 2020 (Black and Bartlett, 2020). Future trade agreements will no doubt rely on maintaining suitable levels of biosecurity and disease-free status for particularly problematic diseases across aquaculture, horticulture and agriculture sectors. Uncertainty exists if legislation will require changing in light of the departure from the EU, and in this case, the aquaculture industry, including the regulatory authority of the FHI and Cefas, must be on hand to assist fish farmers through any transition between legislation.

The industry is facing future uncertainty in the form the potential for a new disease to emerge such as the case of Puffy Skin disease (Peeler et al., 2014) and the incursion of notifiable disease. The continued utilisation of RBS in the industry is warranted, yet what is overlooked by the approach is the potential for the site husbandry and endemic disease prevalence to act as a signifier of potential emergence. By utilising the role of the annual monitoring visits as the primary face-to-face knowledge transfer opportunity, a greater emphasis can be placed on developing a more nuanced approach to the practice of biosecurity beyond what is easily recordable and quantifiable.

The development of technological options to record movements is now being introduced to farmers in the form of the LFM (Live Fish Movements) mobile website. This tool provides the farmer with online access to record live fish movements and in turn, reduce the period taken during the annual monitoring visit that is set aside to gathering and auditing this data. The transporter will be able to generate an online/onscreen Animal Transport Certificate during transit. The most significant positive to be taken from this adoption of technology is that real-time data recording will now allow the FHI to access transport records rather than waiting for the scheduled inspector visits to be confirmed, a key advantage in maintaining the accuracy of the database. By acknowledging that knowledge transfer currently exists between inspectors and fish farmers and developing this element of the annual monitoring visits, the FHI can provide added value on more nuanced disease management or husbandry strategies garnered by their professional experience or the latest available research.

The likely adoption of technological options is individual, the population of fish farmers as previously highlighted, is ageing, with few opportunities for revitalisation of the decision making positions on farms. The FHI must develop an implementation procedure that supports fish farmers in the competence to adjust their record-keeping practice. The utilisation of new technology should not be treated as a panacea. Data that is recorded electronically via an app or through paper records is only as valuable as the accuracy of the farmer recording it and the interpersonal relationships between inspectors and farmers provide a safety net to help identify concerns, therefore, adding key value to the entire RBS approach within the industry.

To conclude, the application of RBS in aquaculture is an effective approach to managing external threats such as VHS and other notifiable diseases. This chapter has identified the opportunity to further develop farmer approaches to what constitutes doing fish farming and biosecurity well. The example of the full utilisation of the biosecurity measures plans questions the ‘meaning’ that drives this practice of biosecurity. If fish farmers do not see the value in this document's development and adjustment, it is unlikely to reach full utilisation across the industry. Incorporating the endemic threats facing farms and their management strategies is a potential addition to the biosecurity measures plans that may foster a firmer buy-in from farmers.

7. Conclusion

This research developed a new understanding of what it means to do biosecurity in finfish aquaculture and what it means to do fish farming well. By way of conclusion, I will provide a chapter overview of the thesis and a summary of the development of new knowledge within each chapter. The project aims and objectives will be revisited to consider the answers that were uncovered alongside the new questions raised and the emergence of practices of care as an integrated conceptual framework for this research. The four key deductions that account for the main contributions to knowledge will then be presented. At this point, there will be a reflection of the limitations of this research. Future research topics will be presented with a focus on the developing trends in biosecurity and the current trade and policy implications of the UK leaving the EU.

7.1 Chapter Summaries

Chapter 2 presented the conceptual framework for this research. It set out the current understanding of biosecurity, from its emergence to the tendency to focus on approaches of closure to the development of more nuanced approaches to disease that refocuses our view of disease from the geometric to the topological, as our globalised world facilitates international transport and trade, dynamically increasing the ability of disease to move within our interconnected global systems. Biosecurity within the context of this sector of aquaculture required a detailed examination, a rapid-evidence-review of the available academic knowledge related to the research trends within trout aquaculture was applied. This investigation identified three broad areas of research focus: 1) Disease, surveillance and vaccination; 2) diet and the role of probiotics; 3) alternative treatment innovation. It identified the gaps in current research related to the concerns of fish farmers.

Chapter 2 also introduced social practice theory as a valuable conceptual tool to understand biosecurity perspectives within an industry. The case is made that social practice theory does not infer meaning and make assumptions on individuals' expected behaviour paths based on other industries or a unique set of circumstances. Instead, social practice theory flips the point of attention to the practice in question and identifies the elements that facilitate its persistence. This provides a useful conceptual lens to view the question of what it means do fish farming well. Social practice theory provided a valuable tool to develop the ethnographic research elements of this project. This was the frameworks most significant contribution to this research. It proved integral to isolate the distinct interactions between fish and fish farmers that may have been overlooked and consider how these actions lead to the emergence of practices of care as a new understanding of biosecurity's role within aquaculture.

Chapter 3 outlined the methodological approaches to conducting this research. The development of the multi-method approach included detailed documentation of the merit and development of a Q-methodology along with a discussion of the important contributions that can be only reached through embedded methods of research such as participant observation and embedded participatory action.

Chapter 4 developed knowledge of what it means to do biosecurity in aquaculture. To achieve this first-hand data was required. A postal survey was used to develop a new understanding of the prevalence and concern across the broad themes of farm characteristics, fish disease prevalence, and doing biosecurity. Through this investigation, several key issues for fish farmers were identified, including endemic disease along with overwhelmingly positive sentiments towards the Fish Health Inspectorate.

This survey data was then supported with an investigation of industry stakeholders' subjectivities on what it means to do biosecurity on fish farms. This thesis argued that the industry shares a consensus on several key biosecurity points by utilising a Q-methodology. It firmly placed fish farmers as responsible for biosecurity and presented the potential to develop knowledge transfer pathways on issues that are of significant value to all stakeholders. The issue of endemic disease threats and the importance of fish stress levels are further raised. Informed by the consensus and distinguishing viewpoints of the Q-methodology data on stakeholder shared perspectives, this research argued for a deeper and more informed understanding of what biosecurity means for fish farmers and how endemic disease management can be viewed as a critical component in biosecurity practice and planning.

Chapter 5 presented rich and detailed accounts of how embedded research methods contributed to the development of care as a significant element in what it means do fish farming well. This concept of care and practices of care was developed through the documentation of a variety of frequent and infrequent fish farming practices that come together to form aquaculture. This chapter argued for the importance of the often-overlooked daily practices that form the basis of what it means to keep fish healthy and sites secure from disease outbreak. Importantly for this research, it is the emergence of practices of care that prove of greatest value to this research as a contribution to a new understanding of biosecurity.

Chapter 6 investigated the current strategy of risk-based surveillance in the finfish industry as a means to protect from the ingress of non-native or notifiable disease threats. This is approached through the documentation of the regulatory agencies only scheduled face-to-face interactions with fish farmers in annual monitoring visits. How these visits develop and the mutual respect that emerges between both sides of the regulatory structure provides a new understanding of the potential for such visits to become more than just audit opportunities. By approaching the relationship between fish health inspectorate/inspector and fish farmer, chapter 6 presents a very different manifestation of care. In this sense, care is at the industry level as stakeholders must balance their regulatory responsibilities with efforts to encourage more favourable on-farm practices. Together with chapter 5, these chapters strongly advocate for the need to view practices of care at both the farm and regulatory level as an essential component in what it means to do biosecurity well on farms.

This work's embedded nature provided a unique account of the key daily, annual and seasonal practices of fish farmers and developed their role as custodians of their stock. Of particular importance was how fish farmers maintain a balance between the population health of their stock and the farm's ability to undertake attentive care practices. Examples of care practices that underpin aquaculture and biosecurity are the daily feeding and mortality removal to the seasonal vaccination of stock. This research is well placed through detailed ethnographic methods to offer new understandings of what it means to protect and safeguard a fish farm from the omnipresent threat of disease and the undeniable worry of what upstream issue may impact a farm.

7.2 Aims & Objectives Revisited

This research set about addressing the overarching aims of:

1) This research aims to determine a new understanding of the underlying drivers of the management and mitigation practices related to biosecurity and fish health in the freshwater finfish industry of England and Wales.
2) To contribute to the current academic knowledge of biosecurity through a theoretical framework of practice theory, a previously unutilised framework with respect to aquaculture.

These aims will be achieved by completing the following objectives:

1) To investigate the range of the finfish farming industry in England and Wales and highlight the key drivers of fish health, security and disease.
2) To identify and explore the factors (social, environmental, market, regulatory, etc) that influence behaviour and attitudes towards biosecurity, faced by fish farmers on a day-to-day basis. Practice theory will be vital to unpack the complexity of these interactions and links between the varying elements comprising the aquaculture industry.
3) To investigate the potential for divergent opinions between fish farmers and regulators on what constitutes biosecurity, the hierarchy of biosecurity concerns and how to best implement management practices on farm level.

This research sought to develop a new understanding of the underlying drivers of the management and mitigation practices related to biosecurity and fish health. Social practice theory was selected as an appropriate framework to develop these issues and address the aims and objectives outlined. However, as this research developed, it was apparent that while social practice theory was very beneficial in developing the focus on the practices and interactions between fish farmers and their stock, an emergent theme developed into an integral element of this research. Indeed, this focus was on investigating farming practices that unlocked the underlying theme of practices of care and how they were to manifest through human-fish relationships and later during stakeholder and regulatory relationships. The decision was made not to alter the aims & objectives to reflect this conceptual approach's adjustment. As this research developed, so too did the conceptual approach that was to prove most important. Without the earlier focus of social practices, it is difficult to say if care would have emerged in such a significant way. Addressing the emergence of care in chapter 5 tracks this research's development and highlights the importance of those underlying factors that may prove challenging to identify at the on-set of this research. Chapter 6 illustrates that practices of care exist beyond the boundaries of the pond and the farm and are in existence in the regulatory space between the FHI and fish farmers.

With that accounted for, this research developed a new understanding of the drivers behind biosecurity at the farm level and applied an emergent theme of practices of care to the concept of biosecurity within aquaculture.

7.3 Deductions

Following the four-stage methodological process, the gathering of data, its analysis and subsequent discussion, four principal deductions on what it means do fish farming well and carry out effective biosecurity in aquaculture emerge from this research.

7.3.1 The persistent threat of endemic disease

Fish farmers have expressed the need for more knowledge and information on disease and, notably, endemic disease issues. Throughout this research, fish farmers have been documented, responding to the omnipresent threat of endemic disease. As in the case of enteric redmouth disease vaccination protocols, the presence and circulation of the practice of vaccination and the financial supports required are critical to implementing this disease management strategy. Similarly, the stock management and herd immunity approach to proliferative kidney disease result in substantial losses in the first year of the stocks life. Biosecurity practices on fish farms are not black and white choices for farmers. These choices are influenced by a host of factors from market, environment, regulatory, skill and knowledge. The decision to vaccinate a population of fish may appear to be a logical step for policymakers absent of the on-the-ground experience of the pressures facing farmers to make their farms viable while protecting to the best of their ability the health of their stock. Farmers must consider if the competence and material to carry out vaccinations are available on the farm. If not, then what is the cost-benefit of outsourcing the vaccination task to contractors?

Stakeholder emphasis on endemic disease is not unique to aquaculture. There is a growing movement to target endemic cattle diseases that have been previously regarded as production diseases. The case of Bovine Viral Diarrhea (BVD) is worthy of note. Farmers and veterinarians consider BVD as one of the most significant diseases infecting cattle. Barrett et al., (2011) note that while voluntary programmes of eradication make initial steps, they ultimately fail. Therefore, a systematic approach that captures farmers' buy-in is essential. Barrett et al., further note that ‘for such a programme to be successful, it must be systematically coordinated. International experience indicates that an aggressive short to medium programme is likely to bring the most success. Protracted campaigns lead to disease control fatigue as awareness and motivation wanes, leading to complacency and cynicism’ (2011:10). Approaches to BVD and other endemic cattle diseases such as bovine Johne’s disease (Geraghty et al., 2014) can act as a signal to the aquaculture sector that endemic disease reform is possible with the appropriate stakeholder buy-in and systematic approach to the problem. However, such attempts would require ‘laboratory, database and human resources as well as industry buy-in and legislative support’ (Barrett et al., 2011:10)

7.3.2 Care practices an integral element in biosecurity

This research developed a rich understanding of what it means to do the practice of fish farming well by developing what may on face value appear as transactional husbandry tasks (supply stock with a predefined quantity of feed – anticipate growth increase in line with feed conversion ratios). They are much more than routine tasks, these daily, weekly and seasonal interactions between human and fish present care practices that safeguard the farm and broader industry from disease outbreaks. They connect the farmer to their stock and present opportunities for the early detection of clinical disease symptoms.

Care practices are central to successful and actionable biosecurity practices. Shove et al., (2012) argues that social practice theory offers unique insights into how certain practices come into existence and are maintained over time. While farming methods vary from site to site, the constant meaning that exists is that of caring for the stock, promoting their health and well-being that will, in turn, facilitate an economic return for the investment placed in the stock. This research has utilised social practice theory to better conceptualise and identify nuanced approaches to biosecurity through care practices and what it means to do fish farming well.

Doing fish farming well occurs through the moments of pause and reflection that intersperse the daily tasks offer opportunities for farmers to connect with their stock, to identify anomalies or suspicious patterns of behaviour. Although a push towards automation and technology does not necessarily mean that care is being withdrawn, there is an understanding that fish farmers are guardians of their stock. The words of Simon (fish farmer),

“fish die for fun”

remain a constant reminder of the precarious balancing of water, oxygen, feed, and biological life unique to each fish farm. The human-animal connection between stock and stock-person bonds individual farmers to the fate of their farm and the lives of their stock, This thesis argues that central to the sustainability of the industry is the robustness of trout farms to biosecurity threats and that care practices are an integral part of securing this robustness.

The ageing demographic of the fish farming population and the physically demanding nature of the work is a warning for the future of the industry. Efforts must be taken by experienced farmers to retain young enterprising individuals in the industry. A loss of this population of young farmers in conjunction with market forces and alternative employment opportunities may lead to the closing of fish farms when the current farmers retire or consolidate farming efforts to a small number of highly productive sites**.**

This work argues for the growing significance of practices of care in biosecurity research. Within the context of aquaculture fish farmers are the custodians of care. Through constant, diligent negotiation and tinkering, they must balance economic pressures and production goals with their stock's stability and maintain their resilience to both endemic and notifiable disease issues. Through this research, practices of care have been witnessed and critiqued to show their variability from situation to situation and the individuality of what one farm needs compared to another. Care is also reflected at the industry level through the actions of the Fish Health Inspectorate. The inspectorate is uniquely placed to provide industry care. The relationships developed and maintained between Inspectors and fish farms highlight the tangible impact institutional care can have.

There is a requirement for constant negotiation and tinkering to accommodate the systems of commerce and production with which there is an uneasy relationship. Whilst good care does not assume a prescriptive form. It nonetheless relies on the willingness of the fish farmers to exhibit and openness to effective encounters.

Perhaps of most importance to this thesis's place within academic knowledge is the call to take care seriously when examining biosecurity actions on farms. This work's contributions demand that biosecurity must turn its focus to the actions and contributions of farmers in the lives of their stock from a place of care. Practices of care is the emerging trend in biosecurity research (Higgins et al., 2018; Maye and Chan, 2020). This thesis adds to the development of this focus from a niche sector of agriculture. The presence of practices of care within this cold-blooded industry furthers the call to explore a new biosecurity that places care practices at the centre of the focus. This focus on care in biosecurity underlines the significant contributions that this work offers to the wider debates on biosecurity.

7.3.3 An industry united.

This research has uncovered a collectively shared viewpoint on several issues that play a significant role in the biosecurity of the industry. Key biosecurity and disease mitigation strategies have been identified as valued and active within the field. These strategies mirror those accounted for by Oidtmann et al., (2012) in the critical importance of the sourcing live fish or eggs of the highest quality.

This research has identified stress in fish as a problematic feature that can lead to disease issues on farms. Additionally, fish stress is a challenging prospect for some farmers to deal with. However, there is an acceptance that the responsibility for biosecurity is primarily with fish farmers. The actions taken by farmers weigh heavily on their minds when their decisions have the potential to result in loss of stock. The potential for sudden catastrophic loss of life due to a water source or circulation issue is hard to avoid, as is the burden that rests on fish farmers' minds. The segregation in production style between the highly industrialised table sector and the small to medium restockers is not reflected in fish farmers attitudes towards biosecurity and what it means to do fish farming well.

Throughout this research, fish farmers continued to accept that the primary responsibility for biosecurity within the industry is with fish farmers. This approach extends beyond individual farms and incorporates a sense of identity as described by Naylor et al., (2016:16) as the 'good farmer'. This identity extends beyond traditional farming behaviour and values associated with stock management to include a far more complex approach to shared responsibilities to neighbouring farmers and the shared mission to protect the industry's sustainability.

7.3.4 State - Fish farmer links

One of the most significant findings in this thesis is the importance of the FHI to the industry and the capacity of the inspectors to add value to fish farmers. Across several stages of research (survey, embedded participant research, participant observation, semi-structured interviews and Q-methodology), the role of the FHI was advocated for by fish farmers across all production styles.

Currently, the inspectors are primarily tasked with auditing fish farms and responding to outbreaks or enforcement situations. This thesis strongly supports the concept of developing the role of the field inspectors that utilises their unique industry experience and knowledge of the policy framework and biosecurity information. Fish farmers trust and value the field inspectors. Utilising the existing interpersonal relationships that field inspectors have cultivated, a knowledge transfer pathway exists and should be maintained and developed to further the sharing of both expert and lay knowledge between the regulators and the regulated. Again, this example of practices of care operates at the regulatory level and demonstrates the importance of including a caring perspective at all levels of biosecurity. The closeness of the relationship between the regulators and the regulated is not without its limitations. By highlighting the closeness of the ties between the industry and the inspectors, questions are raised on the ability of the FHI to effectively act as the enforcement authority while engaged in this trusting relationship. These are legitimate concerns that must be considered when addressing the biosecurity system's robustness within the industry. Regulation and enforcement relationships in the aquaculture sector appear comfortable compared to the relationships between farmers, DEFRA and the FSA in the aftermath of the BSE and vCJD crisis. Similar to the industrial poultry sector in the UK table, aquaculture producers are subjected to strict surveillance from retail multiples (Allen and Lavau, 2014). This lens of surveillance is more exhaustive than the annual monitoring visits of the FHI. The FHI must remain mindful of the risks posed by comfortable relationships and continue to rotate inspectors between regions and maintain a distinct enforcement wing of the inspectorate.

Expert-led knowledge production by Oidtmann et al., (2011, 2014a, 2014b), Peeler et al., (2011) and other research scientists and epidemiologists at Cefas is world-leading. However, fish farmers within the trout sector have called for an increase in information on disease issues and farming practices that they relate to the most pertinent disease threats facing fish farms. This suggests a distinct knowledge-gap between expert-led and lay knowledge and what potentially is different disease priorities and concerns. Utilising the identified capabilities of the FHI to bridge this gap between research and on-farm practice is a valuable option for the industry.

Knowledge transfer from farmers to inspectors can also assist in identifying emergent concerns and trends that are not currently accounted for in the RBS approach to biosecurity. This perspective on lay-knowledge is supported by Wynne (1992, 1996) and Woods (2007) who support the value of tacit knowledge and embedded practices. Enticott (2008) goes further to suggest that farmers construct their understandings of disease and the validity of preventative measures through shared experiences. Absent from this idea of shared experience is the British Trout Association, the only notable industrial lobbying group within the sector. The association's impact is limited by membership rates and has focused predominantly on the issue of water abstraction reform in recent years. This research seeks to give fish farmers more agency in the safeguarding of the industry beyond the pond walls and boundaries of their fish farms by vocalising their concerns and priorities that may appear underrepresented by the FHI. Lobbying bodies and regulators must balance the carrot of safeguarding the sustainability of the industry through knowledge transfer and open communication and the regulatory stick of the enforcement authority of the FHI.

7.4 Policy Implications

This research has raised several issues explicitly related to the governmental policy entrusted to secure and support the freshwater finfish industry. The role of the FHI is that of policy enforcement. This research argues for their role within the industry to be expanded. It is unlikely that this research would prompt an adjustment to the regulatory policy in operation. Instead, this research can enact a softer adjustment in Cefas and the FHI management's perspective and operational scope to reflect the added value the inspectors have through their practices of care while engaging with fish farmers. These relationships can extend knowledge and best practice guidance to farmers that directly impact fish health through the practices of care undertaken by good farmers willing to take new knowledge on board.

At several points, this research has referred to abstraction reform. If actioned, abstraction limit reductions could have detrimental effects on the viability of many farms currently operating with industry high levels of water throughput. This potential upheaval to the fish farming process could have a detrimental impact on many of the farms' viability and biosecurity. Reducing the available water flow through a site can significantly impact fish stress levels, prolong the exposure of fish to pathogens in the water and create conditions for more susceptible disease hosts. This research alerts fish farmers and the FHI to the importance of stock care and institutional practices of care in the event of such a change to operating procedures.

7.5 Recommendations for Future Research

To better understand how knowledge transfer pathways operate in the industry, future research could explore the success of delivering new information through the identified network of the FHI. While this research has identified the potential for the pathway, future studies can address the practicality of this pathway.

More knowledge is required into the future pathways for aspiring fish farmers. Graduates of the Aquaculture BSc (Hons), University of Sterling provide a valuable group of newly graduated individuals with a desire to work within the wider aquaculture sector. Social science research can offer further valuable insights into the career pathways graduates of this degree have taken as a means to evaluate if the trout sector of the wider aquaculture industry is an attractive career prospect.

The industry is operating in a time of climate uncertainty. With global temperatures expected to rise and an increase in extreme weather events (IPCC, 2018), disease emergence triggered by environmental changes as the catalyst is a very real threat to the future of the industry. This global issue has seen the ten warmest years for the UK since 1884, all occurring since 2002 (Kendon et al., 2018) Future research is warranted to investigate the climate resilience of the industry from the ground up.

A growing area of research is the presence of anti-microbial resistance (AMR) in food systems (Hockenhull et al., 2017). AMR research in aquaculture has prioritised the global shrimp industry (Tjornber et al., 2020). Future research within the UK trout sector should explore the topic of AMR. An AMR focus in trout aquaculture could focus on the biological load of ponds and the lasting impact of chemical treatments on the stock and the watercourse connected to a farm.

As this research developed, the importance of practices of care was uncovered and proved to be of significant value to this work. This growing trend in biosecurity research requires further investigation within the context of aquaculture. This work, alongside Lien (2005; 2007; 2015) and Lien and Law (2011), provides a foundation for future research to examine practices of care across different aquacultural contexts and sectors. As demonstrated (Chapter 5 & 6) care within aquaculture is not human to animal. Institutional and regulatory care as carried out by the FHI is integral to the sustainability of the industry. Future research is needed to determine how this type of care is manifested in the wake of the UK leaving the EU. How stakeholders react and adjust their business structures to address this challenge is of notable concern, as is the role of the regulatory authority and their engagement with fish farmers on this issue.

7.6 Reflections on the Limits of Research

This research utilised a mixed-methods design to investigate biosecurity and disease management within the freshwater aquaculture industry of England and Wales.

A limitation of this research is the postal survey data. Unfortunately, participant uptake was not at a sufficient level to offer statistical rigour. Efforts were undertaken to boost uptake that proved successful in raising the response rate. However, the final participant number was deemed to be not statistically robust to make definitive statements on. Instead, survey data was utilised to identify and signpost the direction that this research should investigate in the form of relationships between inspectors and fish farmers.

Of all the research methods used, the one that had the most impact and prompted participants' engagement most was the Q-Methodology. Unlike focus groups or the survey that was utilised during this research, participants were in all cases unfamiliar with Q. The initial encounters of participants with the methods was that of curiosity and, at times, scepticism. Upon undertaking the sorting task the participants became fully engaged with the tactile nature of this ranking task.

Often pausing to reflect before shifting cards as they were forced to rank their feelings on the presented statements. Some participants verbally noted to the researcher mid-task that this is a challenging exercise. During the after-task discussions, participants reported they held initial scepticism on the value of the sorting task. Upon completing the task, they were open to the complexity of what biosecurity is and how social science methods such as Q-methodology can contribute to a better and more nuanced understanding of such complex challenges. Additionally, participants left the task with a more considered opinion on what they regard as biosecurity.

What has proved integral to this research is the emergence of practices of care in chapters 5 and 6. This concept joins a growing trend (Higgins et al., 2018; Maye & Chan, 2020) that affirms the place of care within biosecurity and how care can contribute to the goal of safeguarding animal lives and industry sustainability. The key findings of this work point to the important role that practices of care play in safeguarding industries faced by biosecurity threats.

7.7 End Word

This research has brought me to many ponds and raceways across this industry. I have worked alongside a variety of fish farmers, from entry-level workers to angling lovers, enterprising individuals and seasoned fish farmers with decades of experience. I have documented my ethnographic experiences side by side with fish farmers as we cared for live fish as best we could and collected the many dead bodies of fish that perished on fish farms.

By analysing what it means to do fish farming well, I have developed how approaches to disease management, particularly those of fish farmers are understood within this industry. By utilising social science research methods, I have identified and argued for the valuable knowledge that can be uncovered through social science methods that is out of reach of epidemiological approaches to biosecurity and disease management. These dual approaches can complement one another in striving to consider as much relevant data on the role of disease and biosecurity within the trout sector and bridge the identified gaps in research.

The development of a social science lens to view this industry and its biosecurity challenges is an innovative development of how disease management is approached within the industry, demonstrated by applying Q-methodology as a research method within aquaculture.

The emergence of practices of care as an integral component in biosecurity is the greatest contribution of this thesis to the theoretical debate on biosecurity and disease management practices in aquaculture and more broadly. This thesis is positioned to the fore of contemporary biosecurity research that calls for a greater emphasis on the role of care practices in our biosecurity systems (Maye and Chan, 2020).

The spectre of emergent non-native diseases persists. Those threats are relegated for the most part behind the problematic nature of persistent and reoccurring endemic diseases. Reframing the best practice guidelines for biosecurity to reflect fish farmers' concern about endemic conditions will have the desired impact of boosting buy-in while securing the industry from more destructive diseases that threaten emergence or outbreak. This can be achieved by developing the FHI role to facilitate further knowledge transfer between cefas, the FHI and fish farmers.

Appendix 1

Project Information Form

Project Title: 'Sustainable and Secure Fish Farms' Understanding the Social Practices and Processes Relating to Aquaculture and Biosecurity

You are invited to take part in the above study. Before you decide whether to participate, please read this project information sheet carefully. If you have any questions please email the researcher on the contact details provided.

What is the purpose of this study?

This research seeks to gain a better understanding of disease threats and their mitigation as a means to inform future practice and policy.

Why have I been invited?

This invitation to participate has been sent to all site managers/owners of freshwater, salmonid finfish farms in England or Wales.

What will happen if I take part?

If you choose to take part, please complete both the consent form and the survey provided and return them in the stamp addressed envelope, alternatively, you may complete the survey online (website link provided on cover page), ideally by the 31/01/2017 or contact Jamie McCauley (primary researcher) to conduct the survey over the phone. If you are agreeable, the researcher may contact you to discuss the possibility of a follow-up interview/site visit.

Why should I take part?

This research offers you the opportunity to share your unique experience and expertise as a fish farmer, involved in the daily practices and tasks necessary to maintain disease free and healthy fish.

Confidentiality and data protection

All data and information collected throughout this study will be treated as confidential and will only be shared with the research team (Jamie McCauley, as primary researcher and my University of Exeter supervisors). Data will be stored securely and anonymously at the University of Exeter. Interview recordings and electronic files will be stored securely on password protected computers. Research outputs (PhD thesis, publications, and reports) will be anonymised and any direct quotations will not be attributable to individual participants. Although this project is partly funded by the Centre for Environment Fisheries and Aquaculture Science (Cefas), the data will only be made available to the agency in aggregate form.

Who is funding this research?

This research is partly funded by the College of Life and Environmental Science, University of Exeter and the Centre for Environment Fisheries and Aquaculture Science (Cefas)

I have questions, who do I contact?

Please feel free to contact the primary researcher (Jamie McCauley) with any questions through email jm723@exeter.ac.uk or phone: 07950516747

(or Professor S Hinchliffe, Stephen.hinchliffe@exeter.ac.uk, project supervisor)

Consent Form

Project Title: 'Sustainable and Secure Fish Farms' Understanding the Social Practices and Processes Relating to Aquaculture and Biosecurity

Researcher: Jamie McCauley

Research Institution: University of Exeter

☐ I have read and understand the project information sheet and had the opportunity to ask questions

☐ I understand that my data will be treated as confidential (only shared with the University of Exeter research team) and stored in accordance with data protection legislation

☐ I understand that my words maybe quoted in research outputs (PhD thesis, publications, reports), however my name and the name of my fish farm will not be used or appear in any research outputs

☐ I would be willing to participate in a follow up interview/site visit

Name of Participant: ____________________

Signature of Participant: ____________________

Name of Researcher: Jamie McCauley

Signature of Researcher: ____________________

Date: 05/01/2017

UNIVERSITY OF EXETER

Dear Sir/Madam,

Recently you were invited to participate in a short survey entitled 'Sustainable and Secure Fish Farms' Understanding the Social Practices and Processes Relating to Aquaculture and Biosecurity.

In an effort to increase participation levels, I encourage you to return the survey in the previously provided stamped address envelope. In an effort to make your participation easier you may also complete the survey online, via the following website.

https://www.surveymonkey.com/r/FishfarmUOE   Unique Survey Code ____________

Alternatively, if you wish to complete the survey over the phone, I will be happy to arrange a phone call at a time of your convenience.

What is the purpose of this study?

This research seeks to gain a better understanding of disease threats and their mitigation as a means to inform future practice and policy.

Why should I take part?

This research offers you the opportunity to share your unique experience and expertise as a fish farmer, involved in the daily practices and tasks necessary to maintain disease free and healthy fish.

Why have I been invited?

This invitation to participate has been sent to all site managers/owners of freshwater, salmonid finfish farms in England or Wales.

I have questions, who do I contact?

Please feel free to contact the primary researcher (Jamie McCauley) with any questions through email jm723@exeter.ac.uk or phone: 07950516747.

Thank you for your time and participation in this research project.

Best Wishes,

Jamie McCauley

PhD Researcher – Geography

Phone: 07950516747 – email: jm723@exeter.ac.uk

Amory Building, Rennes Drive, Exeter, EX4 4RJ

UNIVERSITY OF EXETER

Fish Farm Survey

Please complete the following short survey and return both the survey and the completed consent form in the stamped addressed envelope provided.

Alternatively

Complete the survey online by accessing this webpage: XXXX

When prompted please input your unique reference number: XXXX

Introduction: Thank you for taking the time to complete this short survey. The following sections will focus on three areas: (1) production and farm information, (2) disease outbreaks and biosecurity concerns, (3) management practices on the farm.

1. Production and Farm Information

Q1: About your fish farm.

Your name:	
Your position/Role on the farm:	
Farm Name:	
Farm Address & Grid Reference:	
Contact Number:	
Email Address:	
How many staff work on site? (Full time equivalence)	
What is the highest/most relevant qualification held by a member of staff?	

Q.2: What type of production does your farm undertake? (Please tick all that apply).

Hatchery	On-grower	Restocker	Table Producer

Q.3: What type of fish do you farm? (Please tick all that apply).

Brown Trout	Rainbow Trout	Carp	Other:

Q.4: What is your farm's average annual production (metric tonnes - number of eggs/fingerlings)?

	Fish for table production (mt)	Fish for restocking (mt)	Fingerlings (thousands)	Eggs (thousands)
Avg Annual Production				

Q.5: Does your farm receive fish or eggs, from other fish farms? If so, how often? (Please tick).

	Never	Weekly	Monthly	Other
Eggs				
Live fish				
Fish for processing				

Q.6: What is the principal water source used onsite? (Please tick).

River	Spring	Reservoir	Borehole	Other:

Elaborate if necessary:

Q.7: Who do you produce fish for? (Please tick all that apply).

Fish farms	Fisheries	Restaurants	Local markets/ farm shop	Super-markets	Export	Other (please elaborate)

Elaborate if necessary:

2. Disease Outbreaks and Biosecurity Concerns

Q.8: Have any of these diseases occurred on your farm in the last five years? (Please tick).

Disease	2016	2015	2014	2013	2012
Bacterial gill disease					
White spot – Ich					
Rainbow trout fry syndrome					
Epizootic haematopoietic necrosis (EHN)					
Rainbow trout gastroenteritis (RTGE)					
Red mark syndrome					
Proliferative kidney disease (PKD)					
Infectious haematopoietic necrosis (IHN)					
Furunculosis					
Enteric red mouth					
Bacterial kidney disease (BKD)					
Viral haemorrhagic septicaemia (VHS)					
Puffy skin disease					
Epizootic ulcerative syndrome (EUS)					
Costia					
Strawberry Disease					
Infectious pancreatic necrosis					
Sleeping disease					
Saprolegnia					
Other:					

Q.9: How concerned are you about the following fish diseases in relation to your farm's productivity? (please circle)

Disease	Not concerned				Very concerned
Bacterial gill disease	1	2	3	4	5
White spot – Ich	1	2	3	4	5
Rainbow trout fry syndrome	1	2	3	4	5
Epizootic haematopoietic necrosis (EHN)	1	2	3	4	5
Rainbow trout gastroenteritis	1	2	3	4	5
Red mark syndrome	1	2	3	4	5
Proliferative kidney disease (PKD)	1	2	3	4	5
Infectious haematopoietic necrosis (IHN)	1	2	3	4	5
Furunculosis	1	2	3	4	5
Enteric red mouth	1	2	3	4	5
Bacterial kidney disease (BKD)	1	2	3	4	5
Viral haemorrhagic septicaemia (VHS)	1	2	3	4	5
Puffy skin disease	1	2	3	4	5
Epizootic ulcerative syndrome (EUS)	1	2	3	4	5
Costia	1	2	3	4	5
Strawberry disease	1	2	3	4	5
Infectious pancreatic necrosis	1	2	3	4	5
Sleeping disease	1	2	3	4	5
Saprolegnia	1	2	3	4	5
Other:	1	2	3	4	5

Q10: Of the diseases listed in Q9, what 3 are the biggest threat to the industry?

Q.11: Which of the following potential upstream threats to fish health and production are relevant to your farm?

Upstream threats	Please tick
Upstream fish farm	
Upstream fishery	
Upstream water treatment plant	
Angling	
Other recreational activities (eg canoeing)	
Low flow rates	
Wild fish	
Upstream restocking	
Upstream fish processing plant	
Other:	
Other:	

Q.12: How concerned are you about the following upstream factors as a threat to productivity and fish health on your farm? ('Concerned' meaning, how they might affect your farm's profitability)

Upstream threats	Not concerned				Very concerned	N/A
Upstream fish farm	1	2	3	4	5	
Upstream fishery	1	2	3	4	5	
Upstream water treatment plant	1	2	3	4	5	
Angling	1	2	3	4	5	
Other recreational activities (eg canoeing)	1	2	3	4	5	
Low flow rates	1	2	3	4	5	
Wild fish	1	2	3	4	5	
Upstream restocking	1	2	3	4	5	
Upstream fish processing plant	1	2	3	4	5	
Other:__________	1	2	3	4	5	
Other:__________	1	2	3	4	5	

3. Management Practices

Q.13: The following is a list of measures which can improve fish health and disease management at farm level. **(A)** In your opinion which are the most effective (tick) and least effective (tick) measures to improve fish health and disease management for the industry in England and Wales?
(B) Tick the measures you implement on your farm?

Measures	Most effective	Least effective	Implemented on farm
Recording fish movements			
Recording feed deliveries			
Investigating causes of disease & mortalities			
Using separate equipment for each pond/sector of the farm			
Disinfection schedules and equipment cleaning			
Removing mortalities (daily)			
Preventing ingress of wild fish			
Preventing stock escapes			
Reducing predator visits			
Vaccinating stock			
Recording site visitors			
Monitoring reports of disease warnings/outbreaks			
Recording water quality entering the farm			
Recording water quality leaving the farm			
Training of staff to be aware of clinical signs of disease			
Recording water temperature			
Other:			

Q.14: What motivates you to implement disease management practices on your fish farm?

Q.15: Does your farm have an insurance policy relating to direct stock losses due to disease?

Yes	No

Q16: If you answered no, what are the reasons for not having insurance cover?

Q.17: Is your farm a participant in any accreditation or quality assurance scheme?

Accreditation or quality assurance scheme	Please tick all relevant
Quality Trout UK	
Freedom Foods RSPCA	
Supermarket quality schemes	
British Trout Association	
Global Gap	
Other:	
Other:	

Q.18: Where do you access information and advice on fish health?

Source	Please tick all relevant
Attending conferences & meetings	
Academic journals & text books	
Completion of short courses & distance learning	
Aquatic animal health specialists	
Other fish farmers	
Industry publications/magazines	
Feed company representatives	
Fish Health Inspectorate	
Finfish News (Electronic Magazine)	
Veterinarians	
British Trout Association	
Environment Agency	
Other:	
I don't access new information	

Q.19: How would you describe your relationship with the Fish Health Inspectorate?
(please circle your answer)

Negative				Positive
1	2	3	4	5
Please elaborate:				

Q.20: How confident are you in the financial viability of your fish farm? (please circle your answer)

Not confident				Very Confident
1	2	3	4	5
Please elaborate:				

Q.21: What are the three biggest threats to the future of your fish farm? (Please elaborate)

1:

2:

3:

Q.22: Who do you think is primarily responsible for biosecurity within the aquaculture industry? Please rank (1 = most responsible - to 7 = least responsible)

Agent	Ranking
Fish farmers	
Cefas - Fish Health Inspectorate	
Environment Agency	
DEFRA	
British Trout Association	
Veterinarians	
Aquatic animal health specialists	

Q.23: Any other issues that we haven't identified that you would like to share?

Q-Methodology statements			
1	Any farm profits are regularly reinvested in the farm	20	Fish farmers regularly share information on disease outbreaks with other fish farmers
2	Current water abstraction reforms have created financial uncertainty in the sector	21	Fish farmers share good practice advice on fish health with other fish farmers
3	Farm profitability is essential for disease prevention	22	The reduction of available treatments makes disease more likely
4	Compensation or insurance against stock loss would make farmers more likely to report possible disease outbreaks	23	The Fish Health Inspectorate work effectively with fish farmers to manage disease
5	Compensation or insurance would reduce the incentives for good biosecurity practices	24	The Environment Agency understands the challenges faced by fish farmers
6	Endemic diseases are a normal part of fish farming	25	Endemic disease outbreaks are rarely reported
7	Fish farmers can reduce the incidence and prevalence of endemic disease	26	Fish farmers who report suspected cases of listed diseases are helping to protect the overall health of the industry
8	Endemic diseases are the biggest disease problem for fish farmers	27	Fish stress is a major contributory factor in disease incidents
9	Government assistance is reserved for exotic diseases	28	Fish farmers are able to manage fish stress levels
10	It is right that government officers focus on exotic disease threats	29	High stocking densities increase the risk of disease outbreaks
11	Fish farmers know how to deal with endemic diseases	30	Disinfection stations and pond specific equipment are practical biosecurity measures
12	Fish farmers know how to identify endemic diseases	31	Fish farmers can reduce disease outbreaks by implementing good biosecurity
13	Biosecurity is solely about preventing exotic diseases	32	Vaccinations are an effective method of fish health management
14	Listed diseases are more dangerous to the industry than endemic diseases	33	Only some fish farmers are quick to adopt innovative farming
15	Good biosecurity involves early diagnosis of disease presence	34	Good quality eggs and carefully sourced juvenile fish can reduce the likelihood of disease outbreaks
16	Incidences of fish disease and parasite outbreaks are on the rise	35	Biosecurity farm plans are regularly used on the farm
17	Fish farmers can control disease threats from upstream	36	Fish farmers are responsible for biosecurity
18	Fish farmers need more information on disease threats	37	Disease is something that farmers can control
19	Fish farmers primarily rely on the feed company for disease-related advice	38	Biosecurity is the main way that disease is controlled

Factor Characteristics			
	Factor 1	**Factor 2**	**Factor 3**
Number of Defining Variables	6	7	4
Avg Rel. Coefficient	0.800	0.800	0.800
Composite Reliability	0.960	0.966	0.941
S.E. of Factor Z-Scores	0.200	0.186	0.243

Standard Errors for Differences in Factor Z-Scores			
Factors	1	2	3
1	0.283	0.273	0.314
2	0.273	0.263	0.305
3	0.314	0.305	0.343

What are the three biggest threats to the future of your fish farm?

Answer Choices	Responses
1.	40
2.	38
3.	30
	40
	1
	Skipped

Respondents	1.	Tags	2.	Tags	3.	Tags
1	EA Abstraction Reform		Fisheries being affected by too high summer water temps consistently		Delisting of trout products - collapse of the table market - swamping the restocking market with cheap poor quality fish	
2	Abstraction reform (reducing flow/increasing costs)		Disease (especially exotic to the UK)		Supermarkets: costly pointless standards, non LAP and GM stance on fish food.	
3	Foreign disease imports		Water framework directive		Pollution	
4	Survival of the industry		Exotic diseases		Slaughter without compensation	
5	Trustworthiness of staff		Physical problems with the fish, disease outbreak		Decreasing population of anglers-impact demand	
6	river levels		disease		preditors	
7	E.A Legislation on abstraction and discharge		E.A Legislation on stocking		Feed Prices	
8	disease		water supply			
9	RTFS		silt levels		water levels/ Ph spikes	
10	Lack of market, poor image of rainbow trout for foo		Increasingly difficult audit parameters costs incurred, work load		Feed costs & medicine costs, availability reduced margins	
11	Costs		Disease			
12	Disease		over ledgislation		feed costs	
13	Demand ceases		Fish good price rises		Other costs; oxygen, electricity continues to rise. It's always difficult to pass on costs to customers!	
14	water quality		imported novel dieases		notifiable diseases	
15	Paperwork and associated licensing. We calculate		Puffy skin is so destructive to fishing revenues.		Lack of support by CEFAS, EA and FHI. EA see my site as revenue stream only.	
16	Cheap low quality production (corn/soy meals + G		Meat producers		Global warming/climate change	
17	Bank loans		Lack of customer support for stockings		Cost of rearing trout	
18	Formalin being banned		Reduced numbers of anglers			
19	Volume of sales		Poor marketing		Competition from other fish species for sales	
20	Abstraction reform		Lack of anglers		Red tape	
21	Sales		Drought		Pollution	
22	Feed prices		Water levels		Global Temperature	
23	Feed costs		Decline in angling		Disease	
24	Feed costs		Fewer anglers - less demand for fish		Diseases	
25	Bureaucracy		EA hates fish farms		Number of fishermen are declining	
26	Water framework directive / abstraction / discharge		Diseases (exotic) and fish movement restrictions.		Movement restrictions / slaughter without compensation!	
27	Food costs/Overheads		Predation		Supermarket!	
28	Water volume		Otters		Other predators	
29	Inefficiency - small scale		Predator losses after release to river			
30	Loss of water due to building new homes		Pollution			
31	Low membership if the angling clubs, leading to re		Over abstraction of water leading to the springs drying up		Polution from ground water getting into the water suddenly (pesticides, fertilisers and farm wastes)	
32	Feed costs/overheads		Predation		Competition	
33	Drop in demand		Removal of antibiotics & prophylactics		Removal of vaccines	
34	Disease		Pollution			
35	Farming and their bad practices					

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